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—Poor Richard

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RECENT ADVANCES IN VIRUS RESEARCH.*

BY

WENDELL M. STANLEY, Ph.D.[1]

Viruses are small infectious agents that can cause disease in man, other animals, plants and bacteria. They range in size from about 10mμ, a size slightly smaller than that of certain protein molecules, in an almost continuous spectrum of sizes up to about 300 mμ, a size slightly larger than that of certain accepted living organisms. A given virus can multiply and cause disease only when within the cells of certain specific living organisms. No virus has been found to reproduce in the absence of living cells. During multiplication viruses occasionally change or mutate to form a new strain which in turn causes a new disease. Viruses were not discovered until 1892 when Iwanowski demonstrated that the causative agent of the mosaic disease of tobacco would pass through a filter that retained all known living organisms. Six years later Beijerinck proved that this agent was not an ordinary living organism and recognized it as a new type of infectious disease-producing agent—namely, a virus. The same year Loeffler and Frosch demonstrated that foot-and-mouth disease of cattle was caused by a virus. The discovery of the first virus disease of man, that of yellow fever, was made in 1901 by Reed and co-workers.

Since the original discovery of the infectious, disease-producing agent known as tobacco mosaic virus, well over three hundred different viruses, capable of causing disease in man, animals and plants have been discovered. Among the virus-induced diseases of man are smallpox, yellow fever, dengue fever, poliomyelitis, certain types of encephalitis, measles, mumps, influenza, virus pneumonia and the common cold. Virus diseases of animals include hog cholera, cattle plague, foot-

* Talk presented at the Medal Day Meeting at The Franklin Institute, October 20, 1948.

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(Note—The Franklin Institute is not responsible for the statements and opinions advanced by contributors to the JOURNAL.)

and-mouth disease of cattle, swamp fever of horses, equine encephalitis, rabies, fowl pox, Newcastle disease of chickens, fowl paralysis, and certain benign as well as malignant tumors of rabbits and mice. Plant virus diseases include tobacco mosaic, peach yellows, aster yellows, potato yellow dwarf, alfalfa mosaic, curly top of sugar beets, tomato spotted wilt, tomato bushy stunt, corn mosaic, cucumber mosaic, and sugar cane yellow stripe. Bacteriophages, which are agents capable of causing the lysis of bacteria, are now regarded as viruses.

The viruses have been separated as a special group of infectious, disease-producing agents by means of several general properties, no one of which is, however, exclusively characteristic of viruses. Nevertheless, no great amount of difficulty has been encountered in the segregation of the virus group. Viruses are characterized by their small size, by their ability to reproduce or multiply when within the living cells of a given host, by their ability to change or mutate during multiplication and by their inability to reproduce or grow on artificial media or in the absence of specific living cells. The sole means of recognizing the existence of a virus is provided by the multiplication of the virus which is, of course, usually accompanied by manifestations of disease. Viruses spread from diseased to normal susceptible hosts by different methods. Some are transferred by direct contact, as when a diseased leaf is caused to rub against a healthy leaf by a gust of wind, or when a normal person or animal comes into direct contact with a diseased person or animal. Such viruses can usually be spread by indirect contact through the medium of non-specific animate or inanimate objects. Some viruses cannot be transferred by direct contact, but require an intermediate host such as a mosquito, louse, or leaf-hopper. In some cases a highly specific intermediate host is necessary, and a more or less definite period of incubation within this host may be required before the virus can be transmitted.

Because properties such as reproduction and mutation have long been considered characteristic of living entities, viruses were, for many years, regarded as living organisms somewhat smaller than ordinary bacteria. However, the isolation in 1935 of tobacco mosaic virus in the form of a crystalline nucleoprotein of unusually high molecular weight and the subsequent isolation of still other viruses in the form of high molecular weight nucleoproteins, some of which were also crystallizable, cast doubt upon the validity of classifying all viruses as organisms. With the exception of virus activity, the properties of some of the smaller viruses are quite similar to the properties of ordinary protein molecules, whereas at the other extreme with respect to size, the properties of the viruses are more nearly like those of accepted living organisms. The viruses, therefore, serve as a bridge between the molecules of the chemist and the organisms of the bacteriologist, and provide us with new reasons for considering that life, as we know it, owes its existence to structure,

to a specific state of matter and that the vital phenomenon does not occur spontaneously, but is possessed in varying degrees by all matter. It is obvious that a sharp line dividing living from non-living things cannot be drawn and this fact serves to add fuel for discussion of the age-old question of "What is life?".

Attempts to learn something about the nature of viruses through studies on their general properties began with Beijerinck's work in 1898 and were continued in different laboratories for over thirty years without too much success. Although Beijerinck and Allard made important contributions, perhaps the most significant work was that of Vinson and Petre during the years from 1927 to 1931 when they showed that tobacco mosaic virus could be subjected to several kinds of chemical manipulations without loss of virus activity. Nevertheless, in 1932 the true nature of viruses was a complete mystery. It was not known whether they were inorganic, carbohydrate, hydrocarbon, lipid, protein or organismal in nature. It became necessary, therefore, to conduct experiments which would yield information of a definite nature. Tobacco mosaic virus was selected for these initial experiments because it appeared to provide several unusual advantages. Large amounts of highly infectious starting material were readily available and the virus was known to be unusually stable. Furthermore, it was possible to titrate or measure the amount of this virus in a preparation with ease and rapidity and with great accuracy. During the course of a wide variety of early exploratory experiments, it was found that the enzyme pepsin inactivated tobacco mosaic virus only under conditions under which pepsin is active as a proteolytic agent. It was concluded that tobacco mosaic virus was a protein or very closely associated with a protein which could be hydrolyzed by pepsin. With this as a lead, efforts were made to concentrate and purify tobacco mosaic virus by means of the methods previously employed in work with proteins. Soon, by means of a combination of procedures involving salting-out, isoelectric precipitation and adsorption on and elution from an inert material, a crystalline material was obtained which possessed the properties of tobacco mosaic virus. This crystalline material was found to be a nucleoprotein with rod-shaped molecules or particles about 280 by 15 mμ in size and with a molecular weight of about 40,000,000. Early skepticism that a virus could exist in the form of a crystallizable nucleoprotein has largely disappeared, chiefly because the results of a vast amount of experimental work have indicated that the virus activity is a specific property of the rod-shaped nucleoprotein.

Tobacco mosaic virus exists in the form of many strains which appear to have arisen by a process similar to that of mutation in higher organisms. Several of these strains have been obtained in purified form by means of differential centrifugation. Purified preparations obtained from plants diseased with different strains of tobacco mosaic

virus were found to possess properties quite similar to, yet in every case distinctive from, those of purified preparations of the ordinary strain. Spectacular progress has been made in the establishment of the nature of the chemical changes which accompany the mutation of tobacco mosaic virus. The amino acid composition of purified preparations of eight strains of tobacco mosaic virus and of two types of influenza virus has been determined. The results obtained with the strains of tobacco mosaic virus indicate that the mutation of a virus can be accompanied by the elimination of one or more amino acids from the virus structure, by the introduction of one or more new amino acids into the virus structure or by a change in the concentration of one or more amino acids present in the virus structure. This work has great significance for it has provided the first information regarding the nature of the structural changes which accompany mutation. Extension of this work may reveal the exact nature of the chemical differences between virulent and avirulent virus strains, and provide important information regarding the mutation process in higher organisms.

Attempts have been made to change the structure of tobacco mosaic virus by means of known chemical reactions *in vitro* in an effort to secure chemically modified active virus. Although several types of chemical derivatives of this virus were produced and were found to possess full virus activity, the inoculation of such virus derivatives to normal Turkish tobacco plants always resulted in the production of ordinary tobacco mosaic virus. The results indicated that the chemical derivatives were converted to ordinary virus following their introduction into the cells of the plant, or, more probably, that the infecting molecules may not necessarily function as exact patterns for reproduction. Despite these results it still appears that it may be possible to make changes *in vitro* similar to those which occur in nature, and thus secure a heritable chemical modification. Obviously this is a field in which important new results can be anticipated.

Following the isolation of tobacco mosaic virus in the form of a crystalline nucleoprotein having individual molecules or particles about 15 by 280 mμ in size, studies were undertaken in several laboratories to determine if other viruses could be obtained in purified form, mainly by techniques involving high speed centrifugation. Some of these purified viruses are crystallizable nucleoproteins having either rod-like or spherical particles. Some are nucleoproteins which have, as yet, not been crystallized. Others are large particles consisting of nucleoprotein, lipid and carbohydrate and possessing, in some cases, a degree of morphological differentiation which resembles that of organisms. Still other viruses have, as yet, defied isolation and purification, possibly, in some cases, because of extreme instability. The viruses which have been purified possess varied shapes and form an almost continuous spectrum of sizes. The smaller rod or spherically shaped viruses appear

to be simple nucleoproteins, some of which can be obtained in crystalline form. These appear to have chemical and physical properties which, neglecting virus activity, would tend to place them in the molecular world. The larger viruses have a composition and properties which are characteristic, not of molecules, but of organisms. The viruses have certainly provided a link between the molecules of the chemist and the organisms of the biologist. Yet there is no place at which a line can be drawn dividing the molecules from the organisms.

The viruses appear to form a continuous series with respect to structure, ranging from the smaller viruses, which are simple nucleoproteins with many properties similar to those of ordinary molecules, on through viruses with a gradually increasing complexity of structure, to the larger viruses, which, with respect to structure and properties, are similar in many respects to organisms. However, it must be remembered that the properties of only a relatively few purified viruses have been determined. In view of the possibility that these represent the more stable and more easily purified viruses, one cannot be certain that a true picture of the chemical and physical properties of viruses as a whole has been obtained as yet. Information regarding the mode of reproduction of viruses is needed most urgently. At present it is not known whether viruses reproduce by fission or by means of some new process. The solution of this puzzle would certainly represent a most important and significant advance, for the basic reactions characteristic of virus reproduction may well represent the fundamental process which characterizes all living things.

Westinghouse Announces Formation of Atomic Power Division.—Gwilym A. Price, President of the Westinghouse Electric Corporation, has announced the formation of an Atomic Power Division which will concentrate solely on the harnessing of nuclear energy for the production of useful power.

According to Mr. Price, the new Division "will be available to undertake atomic energy projects for the United States Government as well as to carry on independent studies. It will conduct research, development, engineering, and any necessary associated construction." It will work closely with the Westinghouse Research Laboratories and with other divisions of the company so as to benefit from their knowledge, experience, and facilities. Location and other details of organization will be announced later.

Hafnium Oxide.—The DeRewal International Rare Metals Company, it is believed, is the only firm in the United States that produces hafnium metal powder commercially. This firm has for the past three years been supplying hafnium oxide to various scientific institutions in this country, for use in research programs. The firm is located in Philadelphia.

Hafnium metal powder is prepared by subjecting a molecularly proportioned mixture of hafnium oxide and metallic calcium to a high temperature, in a closed system. The cooled reaction mixture is treated chemically to remove calcium compounds, after which the metal powder is separated by filtration. Thus obtained it is a heavy black powder, quite flammable when dry; when moist it is safe to handle.

Fast Break-in Procedure for Dodge Cars.—New Dodge cars do not require customary slow and tedious breaking-in because of the proven effectiveness of a protective oil-absorbing chemical coating applied to the cylinder walls of Dodge engines during the past year.

This outstanding advancement in engine manufacturing inaugurated by Dodge has virtually eliminated the possibility of scuffing or scoring piston rings, pistons, or cylinder walls and consequent damage to the engine during either the critical break-in period or after many thousands of miles of engine usage. As a result, new Dodge cars may be driven at a speed of 40 miles per hour for the initial 250 miles without engine damage. Car speed may then be increased at the rate of five miles per hour for each additional 25 miles traveled until the desired maximum speed is attained.

Scuffing or scoring occurs when extreme local heat or pressure resulting from abusive overspeeding or overloading of an engine causes piston rings, pistons, or cylinder walls to expand and pin-point areas of their metal surfaces to flow or drag. The combination of better lubrication and chemical properties of the Dodge protective coating prevents such a flow or drag of these metals and the serious damage which would result from their welding or bonding together.

In applying the protective coating, a chemical process creates on the cylinder walls thousands of minute pockets or pores that trap and retain oil, thereby providing better lubrication. Simultaneously, the process applies to the cylinder walls a protective oil-absorbing coating of manganese iron phosphate crystals that become chemically combined with the cylinder walls and which possess properties that prevent the flow of metal under conditions of extreme heat or pressure.

PROGRESS IN AVIATION.*

BY

THEODORE VON KÁRMÁN.[1]

The year 1948 will be recorded in the history of aviation as a remarkable year. Technical progress is, of course, not a matter of one year; it is the result of efforts and achievements over an extended period of time. There are, however, single facts which have symbolic significance. Such a single fact was the first break through the so-called "sonic barrier"; that is, the first flight of a manned airplane with a speed faster than sound, an event which was announced this year.

The speed of sound is the speed of propagation of pressure effects in the air and it appears somewhat paradoxical to move a vehicle faster than the effect which is produced by its motion. I am afraid, however, that the layman connects with this fact more of a kind of romanticism than is really justified. Since long ago, projectiles move with speeds which are several times greater than the velocity of sound. The artillery man has no difficulty in breaking through the sonic barrier, because projectiles pass through the so-called *transonic* speed range in such a short time that the difficulties which an airplane encounters do not appear. One cannot say that the laws of aerodynamics change if we leave the subsonic speed range and enter the supersonic range. The fundamental laws of classical mechanics apply equally to both ranges. It only happens that both from the mathematical and experimental points of view, the *application* of these laws is relatively easy if the flow of air is entirely subsonic or entirely supersonic. But both the mathematician and the experimental researcher encounter great difficulties if they have to establish practical rules which are valid in the transition range.

The process of transition between the subsonic and supersonic speed range is somewhat analogous to the transition from the so-called displacement ship floating in and on the water surface, to the speed boat riding on the step. In the first case, especially at low speeds, friction represents the main part of the resistance, while in the second case the boat struggles against the bow wave which its motion produces. However, the hydrodynamics of this transition process can be investigated without great intrinsic difficulties. From a practical point of view, it is significant that the man steering the boat *sees* what happens

* Talk presented at the Medal Day Meeting at the Franklin Institute, October 20, 1948. (Read by Mr. W. Laurence LePage, in the absence of the author.)

[1] Professor of Aeronautics and Director of Guggenheim Aeronautics Laboratory, California Institute of Technology, Pasadena, Calif.

in the water, whereas the pilot of the transonic airplane does *not* see the changes in the air flow, shock waves and similar phenomena. The fact is that, in addition to increased drag, which can be overwhelmed by sheer power, significant and sudden changes occur in the stability and control characteristics of the plane, unforeseen by our previous aerodynamic knowledge. This circumstance caused the sacrifice of a number of gallant and experienced pilots both in this country and abroad.

We cannot say that we already have the right airplane for this extended speed range which was opened to aviation in the past year. Nor can we say that we already have acquired exact knowledge of the phenomena of *transonic* aerodynamics. As a matter of fact, the experimental airplanes in the hands of intelligent and courageous test pilots contributed more to such knowledge than experimental research in the laboratory. Maybe our learned boards and committees were somewhat slow in the creation of adequate research facilities.

Another significant fact which will remain in the memory of aviators, aeronautical engineers and economists is the air-bridge leading to the German capital of Berlin. Of course, it is a paradoxical fact to both engineers and economists that we spend calories in the form of gasoline in order to deliver by air calories in the form of coal. This, however, is only one more proof for the fact that the *homo politicus* did not reach yet the stage of the *homo sapiens* who was placed on this earth to find out the laws, and rule over the forces, of nature. On the other hand, this unique experiment of the air-lift to Berlin is more than a testimony to the capacities of the Air Forces, the achievements of the pilots and the extraordinary talent of organization of General LeMay and his collaborators. The possibility of continuous flow of goods by air, as it is done on the surface every day by the railroad and the trucks which fill our highways, is being demonstrated. The relative merit of airplane sizes, shortcomings in design from the cargo point of view, useful progresses, as for example the routine use of radar landing devices, have been revealed. It is up to the engineers and economists to draw the conclusions and determine the reasonable limitations of air transport for the years to come.

As you see, neither of the two facts I have mentioned, the break through the sonic barrier and the grand experiment of the air-lift, represents immediate solution of current problems of aviation. However, I believe they give significant glimpses into the future. Maybe the coming decades will witness the development of airplanes with enormous speeds, thus making contact between continents a matter of a few hours, for the increase of human understanding, and will witness the continuous flow of goods by air in an economic way, for the increase of human comfort.

A MODIFIED METHOD OF ITERATION OF THE PICARD TYPE IN THE SOLUTION OF DIFFERENTIAL EQUATIONS.

BY

GWOH-FAN DJANG, Ph.D.[1]

INTRODUCTION.

Differential equations in engineering and physics of nonlinear and difficult types which cannot be solved by ordinary methods may be solved by a method of iteration developed by Picard. The method is generally given in most books that have a section on numerical integration (1).[2] Starting from a given function fixed by the differential equation and the boundary conditions at the initial point, the dependent variable of the differential equation is obtained through a number of integrations by means of successive substitution. Differential equations of higher orders are solved as a number of simultaneous equations each of the first order. There are two main difficulties encountered when this method is put into practice: (*a*) The convergence of the successive approximations to the true solution is often slow when the interval used for integration is large. If the interval chosen is small, the number of steps required to cover a given range will be increased. The labor of computation in either case is often tremendous. (*b*) The method cannot be used in its original form if the boundary conditions of the problem in question are spread to a number of points. For the method to be applicable, auxiliary methods have to be devised so as to make all the values of the dependent variable and its derivatives definitely specified at the initial point (2).

The present paper suggests a modified form of iteration which converges somewhat faster than the Picard method and may be used directly whether the boundary conditions are spread or concentrated at a single point. It also solves differential equations of higher orders in a more straightforward manner than the method of simultaneous equations employed by Picard.

OUTLINE OF THE METHOD.

Let

$$F\left(\frac{d^n y}{dx^n}, \frac{d^{n-1}y}{dx_a{}^{n-1}}, \cdots, \frac{dy}{dx}, y, x\right) = 0 \qquad (1)$$

be a general differential equation of order n. The problem is to find a function

$$y = \Psi(x), \qquad (2)$$

[1] Professor of Physics and Fluid Mechanics, National Pei-Yang University, Tientsin, China.

[2] The boldface numbers in parentheses refer to the references appended to this paper.

which satisfies Eq. 1 together with given boundary conditions. Now write Eq. 1 in the form

$$\frac{d^n y}{dx^n} = f\left(\frac{d^{n-1}y}{dx^{n-1}}, \frac{d^{n-2}y}{dx^{n-2}}, \cdots, \frac{dy}{dx}, y, x\right). \tag{3}$$

Assume

$$y_1 = \Psi_1(x) \tag{4}$$

as any convenient function that satisfies the boundary conditions. Putting y_1 into the right side of Eq. 3, one may write

$$\frac{d^n y_2}{dx^n} = f\left(\frac{d^{n-1}y_1}{dx^{n-1}}, \frac{d^{n-2}y_1}{dx^{n-2}}, \cdots, \frac{dy_1}{dx}, y_1, x\right), \tag{5}$$

the integration of which will give y_2 together with n arbitrary constants that can be determined from the boundary conditions. Repeating the process, one can obtain y_n from y_{n-1}. The process is completed when $y_n \doteq y_{n-1}$ to the degree of accuracy set beforehand. y_n is then the required solution.

The fact that we start with an arbitrary function, instead of a given function fixed by the differential equation as in the Picard method, has the advantage that the arbitrary function may be chosen as a solution of the differential equation with some of its unmanageable terms first dropped out. This usually can save us quite an amount of labor in the steps of iteration. A following example will illustrate this point.

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COMPARISON OF THE TWO METHODS.

The merits of the two methods may best be compared by applying them to a few examples.

Example 1.

Let

$$\frac{d^2y}{dx^2} + 3x\frac{dy}{dx} - 6y = 0, \quad \text{with} \quad x = 0, \quad y = 1, \quad dy/dx = 1,$$

be the differential equation to be solved. It is an example used by Levy and Baggot (3) for illustrating Picard's method. Solving the equation as two simultaneous equations

$$\frac{dy}{dx} = z, \qquad \frac{dz}{dx} = 6y - 3xz,$$

the successive approximations are:

$$\begin{aligned} y_1 &= 1 + x, \qquad (\text{using } z = 1), \\ z_1 &= 1 + 6x; \\ y_2 &= 1 + x + 3x^2, \\ z_2 &= 1 + 6x + \tfrac{3}{2}x^2 - 6x^3; \end{aligned}$$

$$y_3 = 1 + x + 3x^2 + \tfrac{1}{2}x^3 - \tfrac{3}{4}x^4,$$
$$z_3 = 1 + 6x + \tfrac{3}{2}x^2 - \tfrac{3}{8}x^4 + \tfrac{1}{8}\tfrac{3}{0}x^5;$$
$$y_4 = 1 + x + 3x^2 + \tfrac{1}{2}x^3 - \tfrac{3}{4}\tfrac{9}{0}x^5 - \tfrac{3}{8}x^6,$$
$$z_4 = 1 + 6x + \tfrac{3}{2}x^2 - \tfrac{3}{8}x^4 - \tfrac{3}{8}x^5.$$
$$y_5 = 1 + x + 3x^2 + \tfrac{1}{2}x^3 - \tfrac{3}{4}\tfrac{3}{0}x^5 - \tfrac{3}{1}\tfrac{3}{6}x^6.$$

Using the present method, however, starting with

$$y_1 = 1 + x,$$

the successive approximations are:

$$\frac{dy_2}{dx} = 1 + 6x + \tfrac{3}{2}x^2,$$

$$y_2 = 1 + x + 3x^2 + \tfrac{1}{2}x^3;$$

$$\frac{dy_3}{dx} = 1 + 6x + \tfrac{3}{2}x^2 - \tfrac{3}{8}x^4,$$

$$y_3 = 1 + x + 3x^2 + \tfrac{1}{2}x^3 - \tfrac{3}{4}\tfrac{3}{0}x^5;$$

$$\frac{dy_4}{dx} = 1 + 6x + \tfrac{3}{2}x^2 - \tfrac{3}{8}x^4 - \tfrac{9}{8}\tfrac{9}{0}x^6,$$

$$y_4 = 1 + x + 3x^2 + \tfrac{1}{2}x^3 - \tfrac{3}{4}\tfrac{3}{0}x^5 - \tfrac{9}{3}\tfrac{9}{8}\tfrac{9}{0}x^7.$$

A casual glance will show that the present direct method gives results which converge faster than those of the Picard method. For equations of still higher orders, the difference would be even more pronounced.

Example 2.

Let us take

$$d^2x/dt^2 + p^2x = x^3, \text{ with } p^2 = \tfrac{3}{2}, \text{ and } t = 0,\ x = 0,\ dx/dt = 1,$$

as a second example. It is a differential equation for the oscillation of a simple pendulum. The equation has been used by Moulton (4) as a numerical example in the application of the Picard method. The work of computation in solving the two simultaneous equations is found to be quite heavy.

Using the present method, one may employ either $x_1 = t + t^2$, or $x_1' = (1/p)\sin pt$ as a starting function. Adopting $x_1 = t + t^2$ (note that in the Picard method one would use $x_1 = t$), we get the successive approximations:

$$x_2 = t - 0.25t^3 - 0.125t^4 + 0.05t^5 + 0.1t^6 + 0.071t^7 + 0.017t^8;$$
$$x_3 = t - 0.25t^3 + 6.874 \times 10^{-2}t^5 + 6.25 \times 10^{-3}t^6 - 1.964 \times 10^{-2}t^7 - 9.375 \times 10^{-3}t^8 + 3.2 \times 10^{-3}t^9 + 5.119 \times 10^{-3}t^{10} + 1.551 \times 10^{-3}t^{11} + (15 \text{ more terms}).$$

If, however, the starting function be $x_1' = (1/p) \sin pt$, the second and third approximations are then respectively:

$$x_2' = 0.296t + 0.544 \sin pt + 0.0101 \sin 3pt,$$
$$x_3' = 0.2803t - 0.052t^3 + 0.00132t^5 - t^2[0.0947 \sin pt + 0.0002 \sin 3pt] - t[0.310 \cos pt - 0.0212 \cos 2pt + 0.0002 \cos 3pt - 0.0002 \cos 4pt] + 0.8452 \sin pt - 0.0173 \sin 2pt + 0.0038 \sin 3pt - 0.0001 \sin 4pt.$$

For the sake of comparison, numerical values of x obtained by the present and Picard method are given side by side in Table I. The table shows that x_1' is a much better function to start with than x_1. This is

TABLE I.—*Numerical Solutions of* $d^2x/dt^2 + p^2x = x^3$.

t	Picard's Method	Present (1)		Present (2)	
		x_2	x_3	x_2'	x_3'
0.1	0.0997	0.0997	0.0997	0.0996	0.0993
0.3	0.2934	0.2922	0.2932	0.2928	0.2934
0.5	0.4708	0.4651	0.4708	0.4707	0.4706
0.7	0.6243	0.6114	0.6247	0.6245	0.6265
0.9	0.7505	0.7592	0.7512	0.7513	0.7503
1.0	0.8030	0.8643	0.8038	0.8026	0.8038
1.1	0.8468	0.9849	0.8446	0.8485	0.8487
1.3	0.9205	1.6555	1.2111	0.917	0.9203
1.5	0.9682	3.2125	1.0445	0.960	0.9675
1.7	0.9940	6.7237	2.3570	0.9767	0.9930
1.9	0.9995	13.9640	19.4714	0.9625	0.9854

because x_1' is a solution of the differential equation only with the term x^3 dropped out, while x_1 is not. The present method also proves to be shorter than the Picard method, even coupled with the process of extrapolation as used by Moulton.

Example 3.

Finally let us take the simple example

$$d^2y/dx^2 + y = x, \quad \text{with} \quad x = 0, \quad y = 0; \quad x = 1, \quad y = 0.$$

Here the Picard method cannot be used directly because dy/dx is not specified at the initial point. For the present method, however, it causes no trouble at all. Starting with

$$y_1 = x(1 - x),$$

one can obtain the successive approximations:

$$y_2 = 1 - \tfrac{13}{12}x + \tfrac{1}{12}x^4$$
$$y_3 = x - 1.179x + \tfrac{13}{12}x^3/3! - 2x^6/6!$$
$$y_4 = x - 1.1879x + 1.1797x^3/3! - 1.083x^5/5! + 2x^8/8!.$$

Taking sin 1 = 0.8418, and putting it into the exact solution

$$y = x - \sin x/\sin 1,$$

one will get, through expansion,

$$y = x - 1.188x + 1.188x^3/3! - 1.188x^5/5! + \cdots.$$

It is seen that y_4 approaches the exact solution rather closely in the region considered.

From the above investigations it is seen that the modified form of iteration is superior to the original one practically in every respect.

REFERENCES.

(1) See, for example, LEVY AND BAGGOT, "Numerical Studies in Differential Equations," Vol. 1, pp. 36–62 (1934).
or,
H. AND B. S. JEFFREYS: "Methods of Mathematical Physics," pp. 272–275 (1946).
(2) LEVY AND BAGGOT, *loc. cit.*, pp. 162–170.
(3) LEVY AND BAGGOT, *loc. cit.*, pp. 73–74.
(4) ADAMS AND HIPPISLEY: "Smithsonian Mathematical Formulae and Tables of Elliptic Functions," pp. 235–242 (1922).

Mechanical Hands.—Mechanical "hands," which in dangerous radioactive areas can perform delicate chemical experiments, operate machine tools, and do countless other tasks requiring great dexterity, were demonstrated recently by scientists of the General Electric Company.

Principal part of a device known as a remote-controlled manipulator, the "hands" also proved they could perform such common jobs as slicing an orange, twirling spaghetti on a spoon, pouring liquids from one receptacle to another, lighting a cigarette, boring a hole, and writing a name.

In actual use the "hands" would extend over a protective eight-foot-high wall into a radioactive area but would be operated by remote control from a room outside the area, thus insuring against danger to humans from radiation, the scientists said.

The actual "hands" are similar to the double hooks used by amputees. They are at the lower ends of two arms which descend vertically from two horizontal shafts eight feet high across the top of the wall. Vertical arms come down from these at the other ends, and carry at the bottoms the handles with which the operator controls the device. He is seated and views his mechanical hands, eight feet away, with the aid of binoculars and a four-mirror periscope which looks over the wall. His feet are on pedals which control the grasping action of the "hands."

The general motion of the hooks corresponds to that given the handles, as they are moved up or down, forwards or backwards, or from side to side. In addition the handles can be turned around three axes, by wrist movement, and this causes the hooks to do likewise. While most of the connections between handles and hooks are mechanical, the twisting of the wrists is accomplished electrically. This permits the artificial hands to do something real ones cannot. They can be twisted around completely, any number of times, which is particularly useful when unscrewing a nut, for example.

It is also possible, from behind the wall, to change "hands." A large one can be used for heavy jobs. If the task requires a more delicate touch, the hand can be lowered into a holder and removed. Then the arm is moved to pick up and attach a smaller hand. Another is provided, instead of hooks, with a pair of snips for cutting sheet metal. Even without practice, it is not difficult to do a simple task, such as removing the stopper from a bottle and pouring its contents into another bottle. With practice much more complicated things can be done, such as writing one's name and operating a drill press. In the latter case, the "hands" pick the proper-sized drill from the box, insert it in the chuck, place the work in position, turn on the switch and feed the drill.

Pedals are used to close the "hands" for grasping, because of the fact that most people are accustomed to the feel of a pedal in operating an automobile brake. The pedals themselves are of regular automobile type, and standard auto brake fluid and cylinders are used to transmit their force. It is possible to squeeze an object between the hooks much harder than the ordinary person can with his fingers. On the other hand, by a more gentle push on the pedal, a very light touch can be exerted, so as to break the shell of a hard-boiled egg without damaging the contents.

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ANALYSIS OF THE PARTICLE-SIZE DISTRIBUTION OF THE GRAINS PRODUCING A PHOTOGRAPHIC IMAGE.*

BY

R. P. LOVELAND,[1] H. M. MENIHAN,[1] AND A. P. H. TRIVELLI.[1]

INTRODUCTION.

In a previous paper Loveland and Trivelli (1)[2] reported an investigation of the formation of the grain-size distribution of the silver halide grains of photographic emulsions. Such a particle-size distribution is anticipatory to the events which lead to the formation of the photographic image. In the present paper the authors will deal with the grains of the photographic emulsion layer of approximate commercial thickness which, upon development, become the grains of the image.

About 25 years ago investigations of the sensitivity distribution among the grains of photographic emulsions were made utilizing photographic plates coated with a single layer of grains. This technique was simpler than the use of the relatively thickly coated commercial emulsion, since all the grains in the areas examined were uniformly exposed and uniformly developed. The gradual absorption of scattered light through the depth of multigrain-layer emulsions alters the distribution of the latent image among the different grain sizes. The single-grain-layer coatings also eliminate the complications of development with penetration of a thick coating, that is, exhaustion of developer and increase in the products of development. Undoubtedly, therefore, exposure and development of commercial multigrain-layer emulsions will produce a different size distribution of developed grains. The magnitude of this effect varies with the type of emulsion and the developer.

GENERAL METHOD.

Exposure to light and development are the agents that select those grains of a photographic emulsion that will develop and become the photographic image. The effective sizes of the grains are those of the undeveloped grains, although the ones selected can only be identified after development. Therefore, the size distribution of the silver halide grains which later develop was obtained statistically by using the normally coated film and the usual sensitometric exposure and development. For this, the size distribution of the undeveloped (residual) grains of the developed but unfixed film was subtracted from that of the original

* Communication No. 1175 from the Kodak Research Laboratories.

[1] Eastman Kodak Company, Rochester, N. Y.

[2] The boldface numbers in parentheses refer to the references appended to this paper.

undeveloped film for each exposure-development step studied. The size-frequency distribution of the halide grains *per unit area of emulsion layer* was necessary and was obtained by adjusting the *relative* size frequencies (per 1000) with the grain concentration of each film area in the sensitometric strip obtained by counts with dark-field illumination.

EMULSION.

A silver bromoiodide emulsion containing 2.56 moles per cent of silver iodide was used. The particle-size constants are given in the section, "Structure of the Photographic Emulsion." A photomicrograph of the grains of this emulsion at 2500 diameters is shown in Fig. 1.

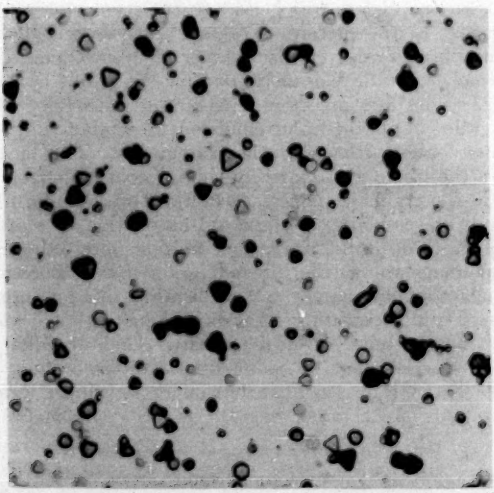

FIG. 1. Photomicrograph of grains of undeveloped silver bromoiodide emulsion containing 2.56 moles per cent of silver iodide (×2500).

Sensitizing was accomplished with a gelatin containing a sulfur sensitizer which gave a relatively low fog. The hydrogen-ion concentration of the emulsion was pH = 7.0. Upon development of the film in DK-50 at 18° C. for 3, 5, and 12 min., the fog densities were 0.03, 0.04, and 0.08, respectively.

Since partial development of individual grains might lead to quantitative errors, which would be particularly undesirable for this type of investigation, this factor was reduced to a minimum by suitable choice of emulsion and developer.

PROCESSING.

The exposure and processing of the film were carried out in the Physics Department of these Laboratories. The 35-mm. film strips were exposed in an Eastman Type IB Sensitometer with a variable-intensity-step scale of exposure through a filter of very narrow wave-band transmission and having an effective wavelength of 426 mμ. The exposure time was 5 min. The film was developed in a machine in DK-50 at 18° C. for 2, 3, 4, 5, 8, and 12 min. An acetic acid stop-bath was used.

The 3-, 5-, and 12-min. strips were selected for special study; the characteristic curves representing them are shown in Fig. 2, the exposures along the logarithmic axis being expressed in ergs.

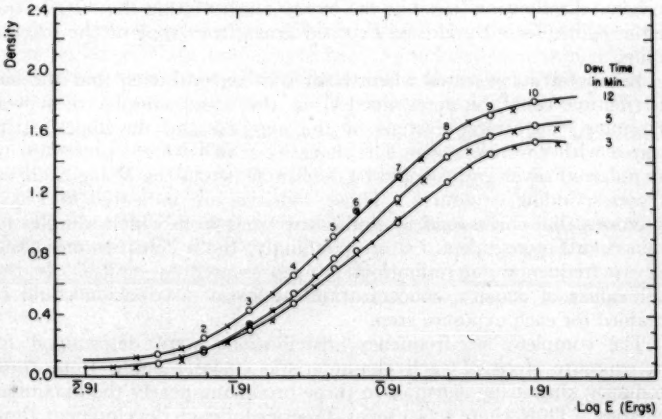

FIG. 2.

× Counts
○ Size measurements

EXPERIMENTAL PROCEDURE.

All the film strips were exposed identically. Groups of these then received identical development to give the series of successive development times. Each of these groups having the same development was then further subdivided into two groups. The first subgroup of strips was then fixed in F-5 fixing bath and washed and dried as usual. Their densities were then measured and plotted to give the curves in Fig. 2.

The remaining strips of successive developing times were dried after the acid stop-bath without fixing and without being exposed to strong light. Areas of carefully determined dimensions were cut from

the uniformly exposed steps on the strips to give a cross series varying in both exposure and development. The emulsion from these film areas was then melted and recoated into a single layer of grains. The technique used varied according to whether the purpose was (*a*) to determine the concentration of grains by counting the number per unit area, or (*b*) to determine the particle-size distribution, because the requirements for the coated plates differ, and better quality is obtained by doing them separately. Obviously the sampling techniques of quantitative analysis were applied for (*a*); the chief criteria for the second purpose are that the measured grains be representative and accurately in a plane, since sharpness of focus affects the apparent size. The developed silver grains were then removed from these plates with chromic acid. The unexposed area of the film was used to make the plates for the "original distribution" used as the base for subtracting the distribution of the light-affected grains of exposed areas from that of the original grains.

Except in a few cases where both the concentration and the size distribution could be determined from the same sample, they were determined on alternate steps of the exposed and developed strips treated with chromic acid. The densities which were represented by the removed silver grains could be determined from the $D/\log E$ curves at corresponding exposures. Those densities are indicated in Fig. 2 by crosses that correspond to equivalent areas from which samples for grain counts were taken. Correspondingly, those densities indicating the size-frequency determinations are represented by circles. In this way values of density, concentration, and size distribution could be obtained for each exposure step.

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The complete size-frequency distributions were determined for ten exposure steps of each characteristic curve ranging from those producing almost fog densities to those producing nearly the maximum densities. Thus, there was a separate series for each development time. Approximately the following numbers of grains were measured to determine the size-frequency curve of the steps for each $D/\log E$ curve:

Step No.:	1	2	3	4	5	6	7	8	9	10
No. of Grains:	4000	3500	3000	2500	2300	2000	1800	1600	1200	800

Trouble was encountered from hardening of the gelatin during remelting of the emulsion, prior to recoating, although no hardener had been used in the emulsion for the first coating. This was partly due to hardening of the gelatin by the quinone, which was formed during development by oxidation of the hydroquinone developer, and partly due to irreversible drying of the gelatin, which was accentuated when the film was cut into small pieces.

After the cause of the hardening was discovered, the film was kept in sealed containers, and small pieces were cut just before use; however, this difficulty with the previously mentioned samples affected the

quality of the recoating, particularly the dispersion into individual grains, and hence must have affected the accuracy of the analytical results.

THE RELATION BETWEEN DENSITY AND NUMBER OF DEVELOPED GRAINS.

Sheppard and Mees (2) state that in a photographic emulsion layer the number of developed grains increases with the exposure, being approximately proportional to the density. Nutting (3), and Silberstein and Trivelli (4) assumed these to be simply proportional to the number of developed grains. We have confirmed this assumption within the limits of experimental error.

Microscopic investigations of cross sections of multigrain-layer coatings have shown that in the majority of cases the exposed and developed grains lie principally near the upper layer, the limit of which is largely determined by penetration effects, whereas the undeveloped grains lie largely in a lower layer with a thickness determined by the coating thickness of the film; therefore, the accuracy of the statistical results of the determination of the number and distribution of the developed grains is dependent to a considerable extent upon a uniform thickness of film coating. Moreover, it follows that with an unequal coating thickness, the errors will be greater for the lower than for the higher densities.

The films used were coated on an experimental scale, a procedure which does not always give a thickness of coating as uniform as the commercial films. About 3000 or 4000 residual grains were counted in the dark field for each exposure step to correlate with the corresponding density:

$$N_d = N_{orig} - N_{res},$$

where

N_d = number (concn.) of the developed grains per unit area;
N_{orig} = number (concn.) of the original grains before development per unit area; and
N_{res} = number (concn.) of residual grains left after development and the silver bleach per unit area.

The last two values were obtained by direct counting. The concentration of the original grains on the untreated emulsion layer, N_{orig}, is a constant,

$$N_{orig} = (0.930 \pm 0.010) \times 10^9 \text{ grains per square centimeter of film.}$$

The probable error, 0.010×10^9, is a measure of the consistency of the counts.

The N_d values, corresponding to the lowest densities, were the most erratic, as was to be expected. Some negative values were even observed among the lower densities; however, when the values of N_d were

plotted against the corresponding densities for each development time, it was found that all were apparently straight lines converging to a point at $N_d = -0.15 \times 10^9$, instead of the origin-locus. This seems to be due to an inherent experimental error, probably a thickness variation of the areas of the emulsion layer from which the samples for the counts of the original concentration were taken. In any case, a logical and simple procedure was adopted, that is, the constant, 0.15×10^9, was added to that of N_{orig}. The corrected value is

$$N_{orig} = 1.080 \times 10^9.$$

The D/N-relations for the different development times are shown in Table I.

The relation between density and number of developed grains per unit area is linear and passes through the origin. A linear formula was applied to the data in Fig. 3 by the method of least squares.

TABLE I.

Development Time, min.	D	N_d(obs.) $\times 10^{-4}$	N_d(calc.) $\times 10^{-4}$	$\Delta N_d \times 10^{-4}$
3	0.36	179	145	−34
	0.58	254	234	−20
	0.80	323	323	0
	1.03	428	416	−12
	1.38	518	558	+40
	1.50	607	606	−1
	1.52	623	614	−9
4	0.07	38	29	−9
	0.12	74	49	−25
	0.24	94	99	+5
	0.40	174	164	−10
	0.62	251	255	+4
	1.09	442	448	+6
	1.23	510	505	−5
	1.44	585	592	+7
	1.56	620	641	+21
	1.58	672	649	−23
5	0.34	170	134	−36
	0.65	253	257	+4
	0.90	371	356	−15
	1.14	402	450	+48
	1.28	472	506	+34
	1.48	601	585	−16
	1.60	604	632	+28
	1.62	696	640	−56
12	0.78	318	304	−14
	1.09	413	425	+12
	1.30	463	507	+44
	1.42	536	554	+18
	1.66	613	647	+34
	1.74	704	679	−25
	1.80	750	702	−48

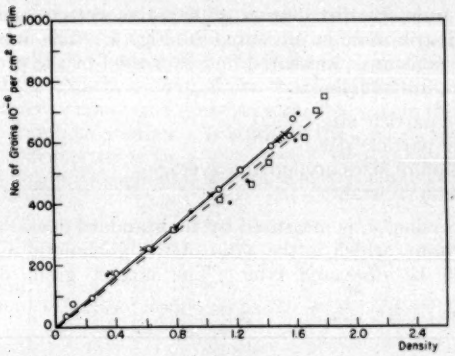

FIG. 3.

○○○ 4-min. obs.
——— 4-min. calcd.
××× 3-min. obs.
● ● ● 5-min. obs.
□□□ 12-min. obs.
- - - - 12-min. calcd.

The formulas obtained are given in Table II.

Of these, the formula for the 4-min. development time is supported most completely by the data.

For this emulsion and within the limits of accuracy of the experiments, the density-number of grains ratio, D/N, is a constant for different development times.

TABLE II.

Development Time, min.	Formula	
3	$N_d = 4.1 \times 10^8 D$	(1a)
4	$N_d = 4.0 \times 10^8 D$	(1b)
5	$N_d = 4.0 \times 10^8 D$	(1c)
12	$N_d = 3.9 \times 10^8 D$	(1d)

STRUCTURE OF THE PHOTOGRAPHIC EMULSION.

The two factors of the structure of the photographic emulsion can be considered to be (*a*) the grain concentration (total number of silver halide grains per unit area), and (*b*) the grain-size distribution. The grain concentration is

$$N = (1.080 \pm 0.010) \times 10^9,$$

where N equals the number of silver halide grains per square centimeter of film.

For the grain-size distribution, 4500 grains were measured; the size-frequency distribution is presented in Fig. 4. The most important particle-size constants, measured and expressed in the projective areas of the grains, are as follows:

Average particle size,	$\bar{a} = 0.50\mu^2$
Medium particle size,	$\bar{a}_{me} = 0.33\mu^2$
Dispersion of sizes around the average,	$\sigma = 0.43\mu^2$
Dispersion constant,	$\bar{a}/\bar{a}_{me} = 1.51.$

The dispersion, σ, is measured by the standard deviation. The dispersion constant, which is the ratio of the arithmetic average to the median, will be discussed later. The largest grain observed was $a = 4.85\mu^2$.

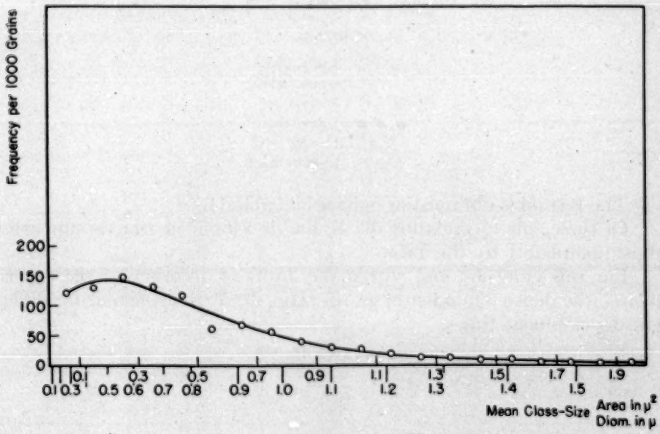

FIG. 4.

The projective area is a very advantageous attribute for the measurement and expression of particle size. First, it is the most important size attribute for this purpose and represents the light-collecting power of the grains. For multilayer emulsions, the total grain area, s, may assume primary importance, but with tabular grains it is about twice the former. Second, the particle size can be expressed and measured, irrespective of the shape of the grain, that is, the "shape factor" does not enter as a limiting assumption to the accuracy.

The normal function plotted on semilogarithmic paper in Fig. 5 shows the distribution to contain a "break" at about $0.9\mu^2$, corresponding to a frequency per 1000 of about 850. Therefore, the emulsion grain must have been formed principally on two types of nuclei (1).

Moreover, Fig. 5 shows that the observed frequency point of $0.55\mu^2$ in the arithmetic size-frequency curve must be an error or a local wave of rhythmic precipitation rather than the point of departure for a break. Experiments by the authors have shown that local fluctuations or waves in the size-frequency curves are quite reproducible within the same emulsion from one batch to another. A study of the various size-frequency curves of the various steps suggests, in fact, that the point of $0.45\mu^2$ should be the height of such a local wave, and the point at $0.55\mu^2$ is too low.

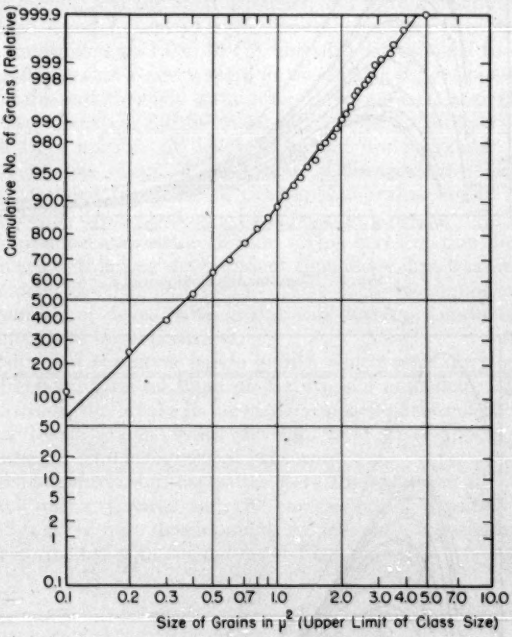

FIG. 5. Log normal function.

STRUCTURE OF THE DENSITIES.

The size-frequency distribution curves of the silver halide grains that will form the image by development are given in Figs. 6 and 7 for the exposure steps receiving 3- and 12-min. development, respectively. The curves are numbered 1 through 10 to correspond to the exposure steps represented by eyelets in Fig. 2. Each curve was obtained by sub-

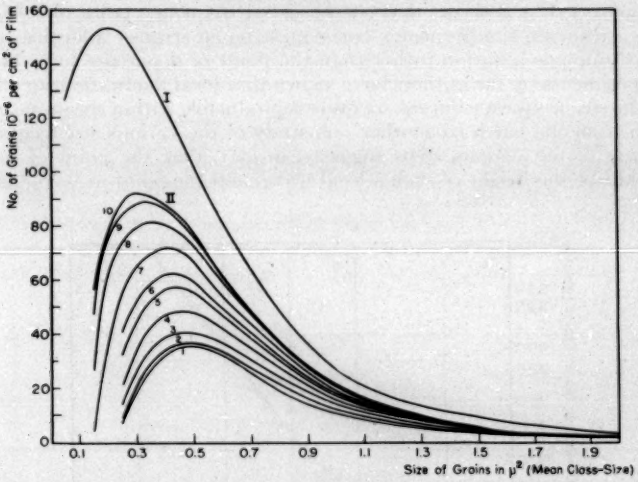

FIG. 6. Three-minute development.

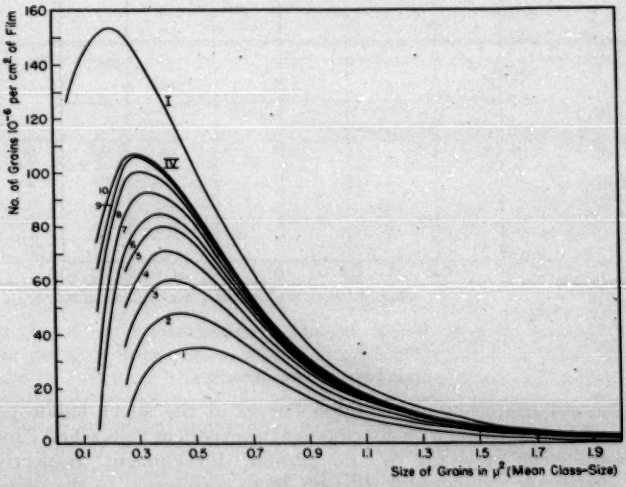

FIG. 7. Twelve-minute development.

traction of the size-frequency distribution data of the residual undeveloped grains from those of the original undeveloped emulsion, proceeding with each class-size progressively. It was first necessary to adjust the size-frequency data, putting the relative size-frequency curves (per 1000 grains) on an absolute basis by multiplying the successive frequency values of each distribution curve by $N_d/1000$, where $N_d = \int y dx$ is the total number of grains per unit area, as determined by the grain counts.

The frequency values used were obtained from the smoothed size-frequency curves, and the total numbers, N_d, were determined by Eq. 1b. In Figs. 6 and 7, Curve I is the size-frequency curve of the original emulsion, multiplied by 1.080×10^6, and also corresponds to the curve of developable grains if every grain in the emulsion developed.

To obtain sensitometric data after development, a photographic emulsion layer is exposed in the usual way. Then, after every exposure there will be a number of developable and undevelopable grains if, for simplicity, the effect of fog grains is disregarded. The density produced by development of all developable grains can be measured sensitometrically from the curve of maximum gamma. This was approached by development for 12 min. This investigation, however, is not restricted to this long development time alone, but was extended to include shorter development times. With such development times, a smaller number of developable grains will develop, producing photographic images of lower contrasts.

The curves of the silver halide grains, which were developed, have the same general form as those of the original emulsion. As the exposure proceeds, the breaks in the size-frequency curves of the developable silver halide grains, which develop, tend to disappear, and the curves assume a simple lognormal (1) form.

The sensitometric step exposures were the same for all film strips. The logarithmic exposures and the corresponding densities obtained after 3-, 5- and 12-min. development, respectively, are given in Table III, to be correlated with the curves of Figs. 6 and 7.

TABLE III.

Curve No.	Log E	$D_{dev.}$ in 3 min. (Fig. 6)	$D_{dev.}$ in 5 min.	$D_{dev.}$ in 12 min. (Fig. 7)
1	$\bar{1}.39$	0.08	—	0.15
2	$\bar{1}.69$	0.16	0.18	0.25
3	$\bar{1}.99$	0.30	0.34	0.43
4	0.28	0.48	0.54	0.66
5	0.55	0.71	0.78	0.92
6	0.70	0.83	—	1.09
7	0.98	1.01	1.17	1.31
8	1.31	1.28	1.44	1.58
9	1.61	1.46	1.58	1.71
10	1.91	1.54	1.65	1.80

The data obtained with 3- and 12-min. development will be considered first and the data obtained with 5-min. development will be used later for grain analysis.

THE SIZE-FREQUENCY CURVES OF THE GRAINS LEFT UNDEVELOPED AT MAXIMUM DENSITIES.[3]

To facilitate the discussion in the subsequent section, the term "developed grains" will be used to designate those developable grains that developed at given times — 3, 5, or 12 min. — as shown by the control strips.

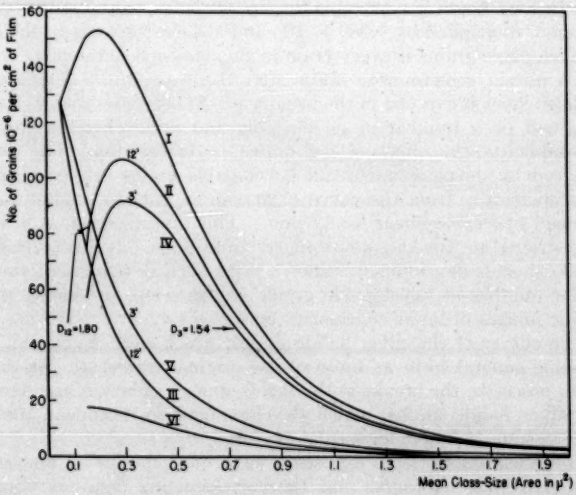

FIG. 8.

When the frequencies of the size distribution of the developed grains belonging to a maximum density for some development time are subtracted from the size frequencies of the silver halide grains of the original whole emulsion, the size-frequency distribution is obtained of the grains that have been left undeveloped. This is represented in Fig. 8, where Curves II and IV, which are the size-frequency curves of the developed grains for the maximum densities, $D_{12} = 1.80$ and $D_3 = 1.54$ for 12- and 3-min. development, respectively, are subtracted from Curve I, which is that of the original emulsion, to give Curve III (I–II) and Curve V (I–IV), which are the size-frequency curves of these undevel-

[3] Owing to the findings of this investigation, the explanation for the occurrence of these grains, as given by Trivelli on page 8 of the JOURNAL OF THE FRANKLIN INSTITUTE, Vol. 241, 1946, must be replaced by the explanation given in this section.

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oped grains that remain substantially unaffected by prolonged exposure at the given development time. Obviously the average size of such grains that apparently cannot be exposed depends upon the development time. The following percentages represent the maximum number of grains that were found to develop at these successive development times:

Development Time, min.	2	3	4	5	8	12
Percentage of Developed Grains	53	56	57	61	63	68

The size-distribution curves of grains corresponding to maximum densities, obtained by development to maximum gamma, are of special interest. Curve III of Fig. 8 represents the grain-size distribution of undeveloped grains which, so far as these experiments are concerned, do not become developable either at the long exposure applied or on prolonged development. These undeveloped grains are not solarized, because prolonged development does not increase the density materially as Trivelli (5) has shown should occur.

A comparison of Curve III with Curve I in Fig. 8 indicates that the smallest grains of the photographic emulsion are not affected by the exposure and development conditions chosen. Curve III shows that the number of undeveloped grains increases very rapidly towards the smaller grains, although it is not a simple exponential type of curve. The average size of these grains is $\bar{a} = 0.350\mu^2$, with a dispersion of grain sizes, $\sigma = 0.427\mu^2$, calculated from the available data, lying above the resolving power of the microscope. The occurrence of undeveloped grains at the maximum density is not new. It has been observed by several investigators. For instance, Trivelli (6) published recently four photomicrographs of such grains among other developed grains.

In this investigation 32 per cent of all the grains of the emulsion at 12-min. development remain undeveloped. These grains show very low sensitivities. They are distributed among the other 68 per cent of more highly sensitive grains over a range of different grain sizes, as shown in Table IV.[4]

TABLE IV.

Mean Class-Size in μ^2	Per Cent Undeveloped Grains
0.05	100
0.15	50
0.25	30
0.35	22
0.45	18
0.55	15
0.65	14
0.75	13
0.85	13
etc.	etc.

[4] For still larger grain sizes, the data become less reliable.

In a few cases it has been possible to show that the grains with very low sensitivities can be made developable by prolonged exposures. This is evident by the slow increase of the density beyond the shoulder of the fog-corrected characteristic curve over a great range of increasing exposures. Such a curve is given in Fig. 9, in which the increase in density is only 0.11 from Log $E = \bar{1}.60$ to Log $E = 1.80$. This curve was obtained from the film coating of a bromoiodide emulsion containing 0.77 mole per cent of silver iodide having an average grain size, $\bar{a} = 2.93\mu^2$, and a dispersion of grain sizes, $\sigma = 2.13\mu^2$. Development was accomplished in 12 min. in DK-50 developer at 18° C.

The occurrence of grains with low sensitivities in many sensitized photographic emulsions explains the problems encountered in the early investigations of sensitivity distributions among the grains of one-grain-layer coatings. Several times a distinct sensitivity difference has been

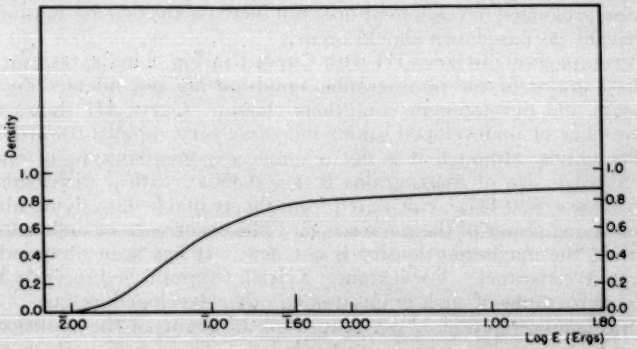

FIG. 9.

observed between the smaller and larger grains of an emulsion, which could not be explained by grain-size differences alone. It was understandable, therefore, that a few investigators restricted themselves to the sensitivity distributions among the larger grains, where a smaller percentage of grains with very low sensitivities was present. This was done in anticipation of an extended investigation to solve the problem for all grain sizes of the emulsion. However, at that time it was found to be possible only with X-ray exposures on unsensitized silver bromide grains (7). If a sensitized emulsion contains grains with both low and high sensitivities, there is a complex sensitivity distribution among the grains of this emulsion. Several cases of such complex sensitivity distributions among the grains of an emulsion have been described previously by Trivelli (8). These grains of extremely low sensitivity, however, complicate the sensitivity problem even more.

Returning to Fig. 8, Curve V = Curve I − Curve IV represents the size frequencies of the undeveloped grains at the maximum density, $D_3 = 1.54$, obtained upon 3-min. development. It is obvious that the frequencies of these grains become smaller with prolonged development until the size-distribution curve, III, is reached. Curve V represents the combined size distributions of the grains with very low sensitivities and the residue of the developable grains which have not yet been reduced by 3-min. development. By subtracting the frequencies of Curve III from those of Curve V, Curve VI is obtained, representing the size distributions of all developable grains left after 3-min. development.

SIZE-DISTRIBUTION RELATIONSHIPS OF THE DEVELOPED SILVER HALIDE GRAINS.

It has previously been considered (9) that the size distribution of the developed grains follows the same law as that of the grains of the original emulsion. The size-frequency distribution of the photographic emulsion that was used to demonstrate this was unusually simple in that it contained no breaks and was well fitted by the simple lognormal function:

$$y = A_o e^{-k(\log x - \alpha_0)^2} \cdot dx. \tag{2}$$

This can also be expressed more appropriately, from our present viewpoint, merely by a change of constants (10):

$$y = \frac{A_1}{x} \cdot e^{-k(\log x - \alpha_1)^2} \cdot dx. \tag{3}$$

The symbols in these equations are those generally used in particle-size investigations.

This conclusion was based on the fact that the curves on double logarithmic paper apparently retained the same fundamental shape and that the curves applied to the data by mere algebraic application of the formula fitted the data quite well. A break in the size-frequency distribution curve as found in this photographic emulsion is more usual, however, and this restricts the application of the simple formulas, 2 and 3, to one segment; the one containing the mode is usually chosen. The operation of fitting this segment to the size-frequency formula is a very helpful procedure. In the series of graphs of the size-frequency distributions of the developed grains of the exposure steps at each development time, it was found that the break in the distribution tended to disappear on prolonged exposure. This is illustrated in Fig. 10, which shows the size-frequency curves of three widely separated exposure steps from a strip developed for 5 min. The curves for other development times are similar.

If this lognormal type of formula applies and the distribution curve is affected as a whole, the parameters of these formulas are fundamentally and usually more simply applicable than the usual statistical con-

stants obtained with the assumption that the Gauss-LaPlace "normal" distribution function is descriptive. For instance, it has been shown (10) that during ripening of a photographic emulsion, the width of the double logarithmic curves is constant, that is, the parameter, k, is an invariant in this case, although the average particle size and the standard deviation are changed.

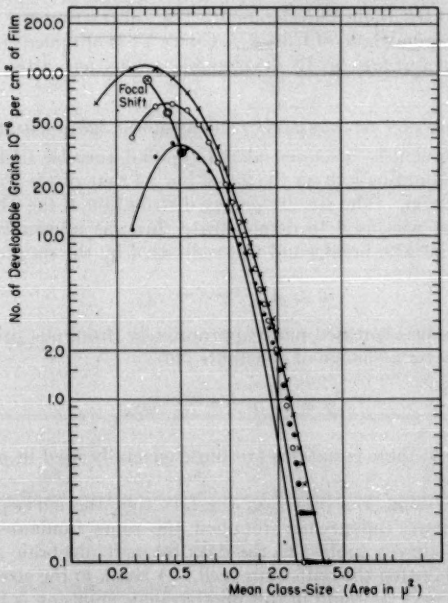

FIG. 10. Five-minute development.

Log E
● 1.69
○ 0.55
× 1.91

Although these parameters can be calculated from their relations with the normal Gaussian parameters, and *vice versa*, they can easily be determined graphically *for a segment or for a whole curve for which the formula applies:*

α_0 = logarithm of the modal size (vertex)—most frequently occurring size;

α_1 = logarithm of the median size = log $\bar{x}_{med}$;

Mk = the width of the log-log curve through the focus (latus rectum), where $M = 0.434$ is the modulus;
A_o = the antilogarithm of the ordinate of the mode; and

k is a measure of the fundamental dispersion of the emulsion, varying inversely with it, so that $K = 1/k$ is a direct measure of the fundamental dispersion:

$$\log \bar{x}_a = \alpha_{\bar{1}} + 1/(4Mk),$$
$$(C_v)^2 = (\sigma/\bar{x}_a)^2 = e^{K/2M^2} - 1,$$

where $\bar{x}_a$ = the arithmetic mean size and σ = the standard deviation.

A simpler measure of dispersion when the distribution is lognormal but has the usual statistical constants is the ratio:

$$\bar{x}_a/\bar{x}_{med} = e^{K/4M^2},$$

or

$$\log \bar{x}_a - \log \bar{x}_{med} = K/4M = 0.5757K.$$

If natural logarithms were used in the lognormal formula, the modulus, M, would, of course, disappear.

The values of $\alpha_{\bar{1}}$ and K are given for the exposure steps of the 3-, 5-, and 12-min. development strips, respectively (Table V).

TABLE V.

Log E	$\alpha\bar{1}$			K		
Development Time	3 min.	5 min.	12 min.	3 min.	5 min.	12 min.
$\bar{1}.69$	−0.193	−0.199	−0.225	0.083	0.080	0.097
0.55	−0.231	−0.249	−0.280	0.115	0.111	0.127
1.91	−0.306	−0.325	−0.321	0.184	0.168	0.191
	$\bar{x}_{med}$ = antilog $\alpha\bar{1}$ in μ^2 (projective area)					
$\bar{1}.69$	0.64	0.63	0.60			
0.55	0.59	0.56	0.53			
1.91	0.50	0.47	0.48			

The trend here is the opposite of that observed with the residual grains. There is a definite but slight decrease in average size of the developed grains with increase of exposure and an increase in the dispersion range of sizes. Figure 11 shows a plot of the change in the average grain size for 5-min. development with increasing exposure, both as the arithmetic average and as the median. The shift is linear with log E but by the relationships shown in the previous pages the two cannot be quite parallel.

It should be noted that the slope of the line exhibiting the relationship between the *average* particle size of a distribution of grains is necessarily less than the direct effect of the particle size, since each

change of particle size with each exposure step principally exhibits the *relative* change of a fraction of grains at the larger end of the distribution that are exhausted and the addition of a fraction of smaller grains entering the affected group.

SENSITIVITIES OF GRAINS OF DIFFERENT SIZES.

Let N be the number of developed grains per square centimeter of emulsion layer of average class-size, $\bar{a}$, for a given exposure and development time. Then the $N/\log E$ curves for such a grain size can be derived from the size-frequency data shown in Figs. 6 and 7 for 3- and 12-min. developments. The data for 5-min. development will be used in this section. They have not been used in this paper up to this point because of their similarity to the data for the 3-min. development.

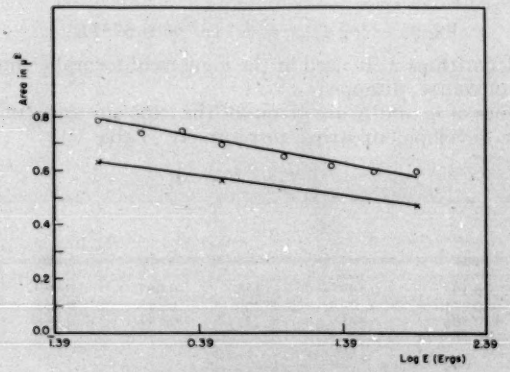

FIG. 11. Five-minute development.
Developable grains
⊙ Arithmetic average grain size
× Median grain size

A picture of the $N/\log E$ curves for the different mean class-sizes, ranging from $0.25\mu^2$ to $1.85\mu^2$, is shown in Fig. 12. All the curves have been smoothed in the same manner as the curve for $\bar{a}_3 = 0.25\mu^2$, for which the observed data are also given. The graph shows that at the lowest exposures nearly all the largest grains are already exposed and developed effectively.

THE AVERAGE SIZES OF THE DEVELOPED GRAINS OF THE DIFFERENT DENSITIES OF THE CHARACTERISTIC CURVE.

The average size of the developed grains of each density of the emulsion layer can be derived from the size-frequency curves of the developed grains for 3-, 5-, and 12-min. development. The results

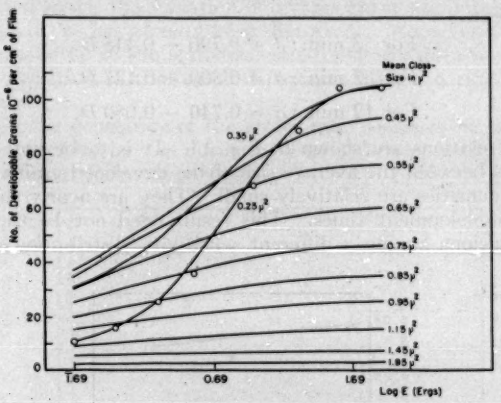

FIG. 12. Five-minute development.
○ N_{obs} for $\bar{a}_1 = 0.25\mu^2$

are collected in Table VI, in which are given the Log E exposures, the densities obtained for different development times, and the average developed grain sizes, $\bar{a}$, in μ^2.

TABLE VI.

3-min. Development

Log E.....	1.39	1.69	1.99	0.28	0.55	0.70	0.98	1.31	1.61	1.91
D	0.08	0.16	0.30	0.48	0.71	0.83	1.01	1.28	1.46	1.54
$\bar{a}$	0.740	0.761	0.778	0.725	0.713	0.702	0.680	0.641	0.620	0.609

5-min. Development

Log E.....	—	1.69	1.99	0.28	0.55	—	0.98	1.31	1.61	1.91
D	—	0.18	0.34	0.54	0.78	—	1.17	1.44	1.58	1.65
$\bar{a}$	—	0.781	0.738	0.745	0.692	—	0.650	0.619	0.597	0.597

12-min. Development

Log E.....	1.39	1.69	1.99	0.28	0.55	0.70	0.98	1.31	1.61	1.91
D	0.15	0.25	0.43	0.66	0.92	1.09	1.31	1.58	1.71	1.80
$\bar{a}$	0.723	0.722	0.722	0.690	0.682	0.672	0.637	0.614	0.590	0.587

If the values of $\bar{a}$ are plotted against the corresponding densities, straight-line relations are obtained which, by the method of least squares, give the following simple equations for the different develop-

ment times:

$$\text{For } 3 \text{ min.}: \bar{a} = 0.790 - 0.115\, D. \tag{2a}$$

$$\text{For } 5 \text{ min.}: \bar{a} = 0.800 - 0.127\, D. \tag{2b}$$

$$\text{For } 12 \text{ min.}: \bar{a} = 0.740 - 0.080\, D. \tag{2c}$$

The $\bar{a}/D$ relations are shown in Fig. 13. It is to be noted that the differences between the average size of the developed grains of the low and high densities are relatively small. They are nearly the same for different development times. This result need not be the same for other emulsions having a different sensitivity distribution among the grains.

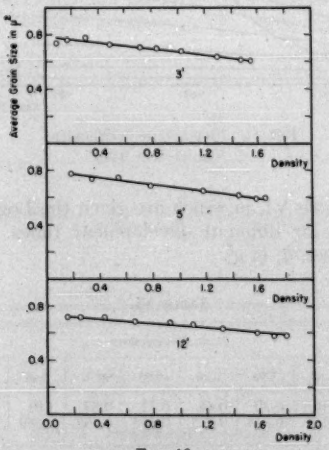

FIG. 13.

THE RELATION BETWEEN DENSITY AND NUMBER OF DEVELOPED GRAINS: RECONSIDERATION.

It will be noted that the graphs of Figs. 3 and 13, as well as the data which they represent, are apparently incompatible. That is, if the size of the average developable grain varies directly with the increase of density obtained with increased photographic exposure, then simple theory would not lead one to expect that the number of such grains would increase linearly with increasing density, since the higher densities must contain a greater proportion of small grains, each contributing less silver. The size-frequency curve is, of course, nonlinear.

In explaining the relation of the observed density-number ratio, (D/N_d), of Fig. 3 and the density-average grain size relation of Fig. 3, at least two factors are involved.

In the first place, the variation of *average* grain size with density is relatively small, as has already been discussed. Moreover, as already stated, the validity of the statistical size-frequency data is much less at the low densities, so that small departures from linearity could not be established.

However, the constancy of the D/N_a ratio seems to be established by Fig. 3, especially by the curve for 4-min. development, within an accuracy sufficient for most purposes.

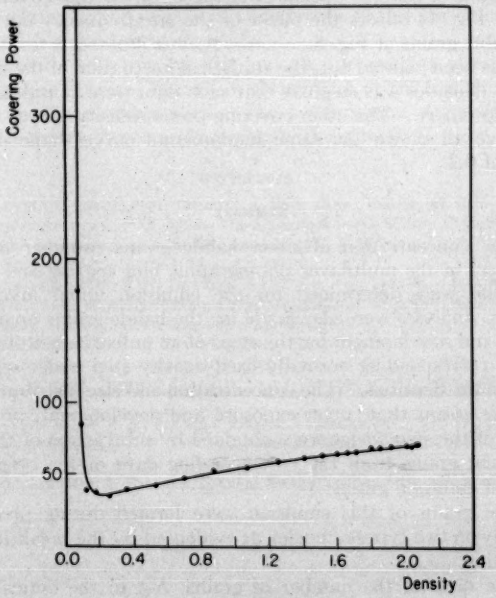

FIG. 14. Twelve-minute development.

Since, according to the above reasoning, only a relatively small nonlinear component is to be expected, this is probably well offset by another one, that is, the greater covering power obtained with decreasing grain size. This factor was studied for this case by means of the analysis of the silver content per unit film area for each density step of the film strips developed for 12 min., which was made for us by Mr. A. Ballard, of these Laboratories. The covering power, which is the ratio,

$$\frac{\text{Photographic Density}}{\text{Grams of Silver per Unit Area}},$$

and which is the reciprocal of the photometric equivalent, is plotted in Fig. 14 against the densities of the sensitometric strip. Considering, for the moment only, the curve above a density 0.2, we know from previous work (11) that the covering power-density curve for shorter times of development, such as 4 min., would be a little steeper (would show somewhat greater gain in covering power with density) and would even become slightly concave upward. That is, the covering power of the silver grains increases for the smaller grains, offsetting their smaller contribution of silver. Specifically, the effect of this covering power curve of Fig. 14 offsets the effect of the size-frequency curves of the developable grains of Fig. 8.

As has been pointed out, the statistical fluctuation of the data at the very low densities was so great that such data were considered too unreliable to report. The other covering power-density curves (11), however, have all shown the same fundamental curve shape down to a density of 0.2.

SUMMARY.

1. The concentration of silver halide grains (number per square centimeter) in the multilayer photographic film coating and their size distribution were determined for the emulsion under investigation. These two analyses were also made for the halide grains unaffected by exposure and development for the steps of an unfixed sensitometric step wedge; a corresponding normally fixed density step wedge was used to determine the densities. The concentration and size distribution of the *developable grains* that, upon exposure and development, produce the densities of the step wedge were obtained by subtraction of the data of the residual grains from the corresponding data of the original total number of emulsion grains.

2. The grains of this emulsion were formed during precipitation principally on two types of nuclei, as evidenced by the break in the normal function.

3. The ratio of the number of grains, N_d, to the optical density, D, is a constant,

$$N_d = 4.0 \times 10^8 \cdot D,$$

which is substantially unchanged between 3- and 12-min. development.

4. The relation between the average size (as projective area) of the developable grains and the density is practically a linear one.

5. The size distribution of the undeveloped grains in the maximum densities, D_{max}, by exposure, with increasing development times, is shown graphically and discussed. About 32 per cent of the grains are still undeveloped as the development approaches maximum development. The size distribution resembles that of a simple negative expo-

nential form, with the smallest grains being predominant in number. These fine grains have a very low sensitivity.

6. A case is cited in which a very slow but definite increase of density occurred upon prolonged exposure after the usual shoulder was reached.

7. Since the size distribution of the residual undeveloped grains of each exposure step resembles that of the undeveloped emulsion in type, the effect of exposure on the statistical size-distribution parameters is presented. For a lognormal distribution, the ratio of the arithmetic average to the median size, $\bar{x}_a/\bar{x}_{med}$, or the difference of their logarithms, is simply related to the *fundamental dispersion*, K, of the emulsion precipitate and is a good measure of it.

8. The arithmetic average size and also the median size of the *developable grains* decrease linearly with increase of the logarithm of the exposure for the range studied. The fundamental dispersion of the developable grains, however, increases with exposure.

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Microfilm Camera for Unusually Large Copy.—A new revolutionary triple-purpose microfilm camera capable of photographing unusually large copy up to 42 in. in width by any length in one continuous exposure was exhibited recently at the showrooms of Diebold Incorporated, New York City.

The camera, which also serves as a film printer and enlarger, is the result of years of experiment by Diebold Laboratories to broaden the application of the automatic flow principal of microphotography to include records and documents wider than the present limitation of 14 in. Its principal applications are in the microreproduction of engineering drawings, newspapers, blueprints, maps, surveys, and large production control and accounting records.

Development of the new Flofilm 42-in. camera, a compact unit which resembles a home laundry mangle and is fed much the same as a blueprint printer, necessitated new engineering designs which would make possible satisfactory photographic results at higher reduction ratios. A reduction ratio of 34 times which reduces the microfilm image to less than 1/1000 the area of the original copy is made possible by inverting the camera so that copy passes over the lens instead of underneath it.

The flow-type camera is capable of microfilming the longest copy in existence in one operation. A 100-ft. roll of film can take copy up to ¾ of a mile in length. Through use of the enlarging feature of the camera, images can be "blown back" at reduced size, original size or larger on a single sheet or roll of paper in one printing operation.

Any desired number of inexpensive contact prints can be made from the original roll of negative film. The camera when converted to a flow enlarger will print blow-ups of any desired image on photosensitive paper or cloth from the roll of negative film.

Copy can be moved through the camera at two speeds of 30 or 60 ft. per minute. At the speed of 60 ft. per minute, a drawing 10 ft. long can be microfilmed at 10 sec. Through a series of five buttons on the control panel, proper light intensity is controlled by the operator by merely touching the button offering the best lighting for any type of copy.

Du Pont Announces New Synthetic—Orlon (*Textile World*, Vol. 98, No. 9).—Orlon, formerly called Fiber A, is the name given by Du Pont to the acrylic yarn it is producing in small quantities at its Waynesboro, Va., plant. Large-scale production is rumored as planned for Du Pont's projected plant at Camden, S. C.

Orlon is technically a polyacrylontrile fiber, commonly called acrylic. Its properties place it between nylon and rayon. Work on it was begun in 1940, and for several years laboratory and pilot-plant production has been used to explore the possibilities of the new fiber in continuous-filament form. Yarn sizes from 30 to 600 den. have been produced. Filaments range from 1 to 5 den.

The new fiber can be used on conventional equipment for winding, twisting, knitting, slashing, weaving, braiding, dyeing, and finishing. Some ultimate uses for Orlon include: automobile tops, cordage, fish nets, laundry bags, electrical insulation, rainwear, bathing suits, curtains, window shades and awnings.

GENERALIZED MAGNETO-IONIC THEORY.

BY

N. C. GERSON[1] AND S. L. SEATON.[2]

ABSTRACT.

A vector equation relating the polarization of a homogeneous isotropic medium to an external impressed magnetic field was derived under the condition that the medium is penetrated by an electromagnetic wave. From the three implicit scalar relationships, a final equation involving the fourth degree of the refractive index was obtained. The identity of the quartic equation with the corresponding relationships of Appleton and Booker under the appropriate restrictive conditions is shown.

INTRODUCTION.

The theory of magneto-ionic refraction in the ionosphere as propounded by Appleton (1, 2),[3] treated what may be considered a one-dimensional propagational case: an electromagnetic wave propagating solely along the Z axis and penetrating a dielectric normal to its surface. Two conditions were stipulated: (1) that the lapse rate of refractive index along Z within the dielectric was so small that for several wave lengths the medium could be considered homogeneous, and (2) that an external static or very slowly varying magnetic field existed which could be resolved into two components, longitudinal (along the direction of propagation of the electromagnetic wave) and transverse (perpendicular to the direction of wave propagation). It was assumed that the transverse component existed along only one of the remaining two coordinate axes. The ionosphere was taken as parallel to and separated from a horizontal flat earth.

Similar treatments were later applied by Nichols and Schelleng (3), Breit (4), Goldstein (5), and Hartree (6). Booker (7) in 1938 advanced the problem by discussing the two-dimensional phase propagational case: an electromagnetic wave propagating linearly in the Y–Z plane and penetrating a plane stratified dielectric obliquely to its surface. He also considered the external magnetic field as possessing two mutually perpendicular transverse components, in distinction to only one assumed by Appleton. The remaining factors were the same as those prescribed above. Thus, under the condition that the angle of incidence of the wave was 90°, and that the transverse component of the magnetic field extended along only one of the coordinate axes, Booker's more general exposition degenerated into that of Appleton's.

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[3] The boldface numbers in parentheses refer to the references appended to this paper.

A logical extension of the above treatments is the complete generalization into the three-dimensional propagational case: an electromagnetic wave in space penetrating a dielectric when the velocity vector is distinct from each of the three coordinate axes. A formulation and development of the problem on these lines is presented for a homogeneous isotropic medium.

In general, the final quartic equation which is obtained does not admit of a ready analytical solution through any of the various devised methods. Because of its complexity, the equation will be solved mainly by recourse to one of the standard numerical methods (for example, Newton's or Horner's method) for the solution of algebraic quartic equations.

SYMBOLS.

$\mathbf{c}$ = velocity of electromagnetic propagation in vacuum,
e = charge of electron,
$\mathbf{E}$ = mean electric intensity of the electromagnetic wave,
$\mathbf{H}$ = mean magnetic intensity of the electromagnetic wave,
$\mathbf{H}^e$ = mean impressed external magnetic field,
$i = \sqrt{-1}$,
m = mass of electron,
$n = \mathbf{S}\cdot\mathbf{c}$ = refractive index of medium,
N = number of bound electrons in the medium,
$\mathbf{P}$ = electric polarization of the medium,
$\mathbf{r} = \mathbf{i}x + \mathbf{j}y + \mathbf{k}z$,
$\mathbf{S}$ = reciprocal of actual velocity of wave in the medium,
t = time in seconds,
$\omega = 2\pi\nu$ = angular velocity,
ν = frequency of electromagnetic wave.

Note that $\mathbf{S} \times \mathbf{c} = 0$.

Components of each of the vectors along the x, y, z axes will be indicated by the subscripts 1, 2, 3, respectively.

Vectors are in boldface type.

FUNDAMENTAL ELECTROMAGNETIC RELATIONSHIPS.

Maxwell's equations for the propagation of electromagnetic waves are, in Heavyside-Lorentz Units,

$$\nabla \times \mathbf{E} = -\dot{\mathbf{H}}/c, \tag{1}$$

$$\nabla \times \mathbf{H} = (\dot{\mathbf{E}} + \dot{\mathbf{P}})/c. \tag{2}$$

The magnetic field $\mathbf{H}$ may be eliminated by taking the cross product of ∇ with (1), the time derivative of (2), and combining equations.

$$\nabla \times \nabla \times \mathbf{E} = (-1/c)\nabla \times \dot{\mathbf{H}} = -(1/c^2)(\ddot{\mathbf{E}} + \ddot{\mathbf{P}}). \tag{3}$$

Expanding the triple vector product,

$$\nabla\nabla\cdot\mathbf{E} - \nabla\cdot\nabla\mathbf{E} + (1/c^2)(\ddot{\mathbf{E}} + \ddot{\mathbf{P}}) = 0. \tag{4}$$

Expression (4) provides the relationship between the electric field of the propagating wave and the polarization of the medium through which the wave passes. As a solution of (4) is desired explicitly in terms of **P**, a second independent relationship involving **P** and **E** under the required conditions is sought. The relationship may be established by examining the dependence of **E** and **P** in a homogeneous isotropic medium which lies in an external magnetic field.

As an aid to the subsequent analysis, a wave solution of the type

$$\mathbf{E}, \mathbf{H}, \mathbf{P}, \text{ etc.}, = \mathbf{A}e^{i\omega(\mathbf{S}\cdot\mathbf{r} - t)}, \tag{5}$$

is postulated for all fields associated with the electromagnetic wave where **A** = constant vector amplitude.

By means of (5) the several differential operators may be replaced by the following algebraic equivalents:

$$\left.\begin{aligned} \frac{\partial}{\partial t} &= -i\omega, & \nabla &= i\omega(\mathbf{i}S_1 + \mathbf{j}S_2 + \mathbf{k}S_3), \\ \frac{\partial^2}{\partial t^2} &= -\omega^2, & \nabla\cdot\nabla &= -\omega^2 S^2, \end{aligned}\right\} \tag{6}$$

etc., provided $\mathbf{S} \neq f(x, y, z, t)$.

POLARIZATION IN A HOMOGENEOUS ISOTROPIC MEDIUM.

The medium under consideration is visualized as being composed of an almost infinite number of regularly spaced atoms, each containing close to its assigned number of asymmetrically concentrated planetary electrons. In penetrating the medium an electromagnetic wave of frequency less than the ionization frequency reacts with some or all of the electrons in its path and sets them in vibration. The relatively massive nucleii, however, remain unaffected by the wave. From a microscopic outlook, the resultant field within the body could be obtained on a statistical basis by integrating, over the entire volume, the combined fields of each electron and each nucleus and the field of the electromagnetic wave. Employing the integrated field equations thus obtained, the interactions of the field on the electrons and the equations of motion for the electrons could be derived. However, the method outlined is subject to great mathematical difficulties unless rather broad assumptions be made regarding the existent highly irregular distribution in time and space of each electron.

A rigorous treatment, nevertheless, may be formulated by classical procedures. In this method the problem is considered macroscopically and mean values of the electromagnetic field are utilized. The assump-

tion is implicitly made that microscopic irregularities, mutual interactions, etc., of the individual nucleii and electrons effectively cancel, leaving only a net gross effect. As the latter effect is the one with which we are concerned, the course outlined immediately above will be followed.

Because of the relative magnitude of the nuclear and electronic masses, each term of the momental dyadic, that is, the moments and products of inertia, for the permanent dipoles will be very much greater than those for the electrons. The rapidly fluctuating electric and magnetic intensity of an electromagnetic wave consequently will affect the lighter electrons to a far greater extent than the massive permanent dipoles. At moderate and high frequencies, the total reaction of the wave with the medium may be regarded as confined solely to producing an oscillatory motion of the electrons. Similar considerations apply to ions in the electromagnetic field, positive ions remaining unaffected.

A mobile electron (in a homogeneous isotropic dielectric) whose motion has been induced by interaction with an electromagnetic field is subject to two forces: (*a*) a force of restitution, proportional to the displacement of the electron, which acts to restore the electron to its equilibrium position, and (*b*) a damping force, proportional to the electron velocity, which acts to resist motion. When an external magnetic field is impressed upon the medium, a third force exists—a magnetic force, proportional to the external magnetic field—which acts to change the velocity of the moving electron.

It should be noted that the model of a homogeneous isotropic dielectric was taken to provide generality of treatment. In the ionosphere there exist free electrons and ions, much in the manner of a spherical shell of somewhat rarified electron gas. The distinction between the model of a dielectric and that of an electron gas becomes evident in the restitutive force term. With a dielectric this term exists, but with an electron gas no such restoring force arises. Thus, when the discussion later is restricted to the ionosphere, this term vanishes. Also, the damping force term, due to irreversible energy absorption from the electromagnetic field, proceeds from electron collisional and recombinational activity.

In the development which follows, a steady state condition, for example, one which exists after unlimited wave trains have traversed the medium for a time long in comparison with the vibratory period, will be considered. The discussion is restricted to low electron velocities ($c \gg \dot{\mathbf{r}}$), thereby making it possible to neglect the relativistic variations of mass with velocity. Under these circumstances, the motion of an electron subject to the simultaneous action of an external electromagnetic and impressed magnetic field is given by:

$$m\ddot{\mathbf{r}} + m\dot{l}\dot{\mathbf{r}} + mk^2\mathbf{r} = e[\mathbf{E}' + (1/c)\dot{\mathbf{r}} \times \mathbf{H}'], \tag{7}$$

where

$$\begin{aligned}
\mathbf{E}' &= \mathbf{E} + (1/3)\mathbf{P} = \text{total mean electric field,}\\
\mathbf{H}' &= \mathbf{H} + \mathbf{H}^0 = \text{total mean magnetic field,}\\
m\ddot{\mathbf{r}} &= \text{accelerating force on electron,}\\
-ml\dot{\mathbf{r}} &= \text{damping force on electron, and}\\
-mk^2\mathbf{r} &= \text{restorative force on bound electron.}
\end{aligned}$$

Since $\mathbf{E}$ and $\mathbf{H}$ are of the same order of magnitude, and since $|\dot{\mathbf{r}}| \ll |\mathbf{c}|$, the term $(\dot{\mathbf{r}} \times \mathbf{H})/c$ is negligibly small in comparison with $\mathbf{E}$ and may be neglected. Discarding the term involving $\mathbf{H}$, (7) may be rewritten as

$$m\ddot{\mathbf{r}} + ml\dot{\mathbf{r}} + mk\mathbf{r} = e[\mathbf{E} + (1/3)\mathbf{P} + (1/c)\dot{\mathbf{r}} \times \mathbf{H}^0]. \tag{8}$$

To simplify (8) note that the periodic oscillation of the electron permits the utilization of the relationships (6), whence

$$\ddot{\mathbf{r}} = -\omega^2\mathbf{r}, \qquad \dot{\mathbf{r}} = -i\omega\mathbf{r}. \tag{9}$$

Further simplifications in (8) may be made as follows: by defining the dyadic

$$\begin{aligned}\mathbf{\Psi} = \mathbf{ii}0 + \mathbf{ij}H^0_3 - \mathbf{ik}H^0_2 - \mathbf{ji}H^0_3 + \mathbf{jj}0 + \mathbf{jk}H^0_1\\ + \mathbf{ki}H^0_2 - \mathbf{kj}H^0_1 + \mathbf{kk}0,\end{aligned} \tag{10}$$

the cross product $\dot{\mathbf{r}} \times \mathbf{H}^0$ may be replaced by

$$\dot{\mathbf{r}} \times \mathbf{H}^0 = -i\omega\mathbf{r} \times \mathbf{H}^0 = -i\omega\mathbf{\Psi} \cdot \mathbf{r}. \tag{11}$$

Use will also be made of the idemfactor

$$\mathbf{I} = \mathbf{ii} + \mathbf{jj} + \mathbf{kk}. \tag{12}$$

Employing Eqs. 8 to 12, (7) becomes

$$(k^2 - \omega^2 - i\omega l)\mathbf{I}\cdot\mathbf{r} = (e/m)[\mathbf{E} + (1/3)\mathbf{P} - i(\omega/c)\mathbf{\Psi}\cdot\mathbf{r}]. \tag{13}$$

Elimination of $\mathbf{r}$ may be accomplished through the elementary electrostatic formula

$$\mathbf{P} = Ne\mathbf{r}. \tag{14}$$

Thus

$$(m/Ne^2)[(k^2 - \omega^2 - i\omega l - Ne^2/3m)\mathbf{I} + i(e\omega/cm)\mathbf{\Psi}]\cdot\mathbf{P} = \mathbf{E} \tag{15}$$

or

$$a\mathbf{P} + b\mathbf{\Psi}\cdot\mathbf{P} = \mathbf{E}, \tag{16}$$

if the complex constants a and b are defined by

$$\left.\begin{aligned} a &\equiv (m/Ne^2)(k^2 - \omega^2 - Ne^2/3m - i\omega l),\\ b &\equiv (i\omega)/Nec.\end{aligned}\right\} \tag{17}$$

Equation 17 provides the second relationship involving $\mathbf{P}$ and $\mathbf{E}$ which was necessary for the solution of (4). Solving (17) and (4) simultaneously for $\mathbf{P}$

$$[a(\nabla\nabla - \nabla\cdot\nabla\mathbf{I}) + b(\nabla\nabla\cdot\Psi - \nabla\cdot\nabla\Psi)]\cdot\mathbf{P} + (1/c^2)(1+a)\ddot{\mathbf{P}} + (b/c^2)\frac{\partial^2}{\partial t^2}(\Psi\cdot\mathbf{P}) = 0. \quad (18)$$

Inasmuch as $\Psi \neq F(t)$

$$\frac{\partial^2}{\partial t^2}\Psi\cdot\mathbf{P} = \Psi\cdot\ddot{\mathbf{P}} = -\omega^2\Psi\cdot\mathbf{P} \quad (19)$$

and (18) becomes

$$\Theta\cdot\mathbf{P} = 0, \quad (20)$$

where

$$a(\nabla\nabla - \nabla\cdot\nabla\mathbf{I}) + b[\nabla\nabla\cdot\Psi - \nabla\cdot\nabla\Psi - (\omega^2/c^2)\Psi] - (\omega^2/c^2)(1+a)\mathbf{I} \equiv \Theta. \quad (20a)$$

Equation 20 provides the relationship between the polarization of a homogeneous isotropic medium and an impressed magnetostatic field under the condition that the former is penetrated by an electromagnetic wave and that **S** is not a function of either time or space. Under the same circumstances, (20) is also valid for an electron gas if the term containing k is eliminated.

The rather powerful vector equation (20) may be made more amenable to solution when written in terms of its three scalar relationships. The algebra is straightforward but cumbersome.

Note that the various terms may be expanded by the use of:

$$\nabla\nabla\cdot\mathbf{P} = -\omega^2[\mathbf{i}(S_1^2P_1 + S_1S_2P_2 + S_1S_3P_3) + \mathbf{j}(S_1S_2P_1 + S_2^2P_2 + S_2S_3P_3) + \mathbf{k}(S_1S_3P_1 + S_2S_3P_2 + S_3^2P_3)]. \quad (21)$$

$$-\nabla\cdot\nabla\mathbf{P} = +\omega^2[\mathbf{i}(S_1^2 + S_2^2 + S_3^2)P_1 + \mathbf{j}(S_1^2 + S_2^2 + S_3^2)P_2 + \mathbf{k}(S_1^2 + S_2^2 + S_3^2)P_3]. \quad (22)$$

$$\Psi\cdot\mathbf{P} = \mathbf{i}(P_2H^\circ_3 - P_3H^\circ_2) + \mathbf{j}(P_3H^\circ_1 - P_1H^\circ_3) + \mathbf{k}(P_1H^\circ_2 - P_2H^\circ_1). \quad (23)$$

$$\begin{aligned}\nabla\nabla\cdot(\Psi\cdot\mathbf{P}) = &-\omega^2\{\mathbf{i}[S_1^2(P_2H^\circ_3 - P_3H^\circ_2) + S_1S_2(P_3H^\circ_1 - P_1H^\circ_3) + S_1S_3(P_1H^\circ_2 - P_2H^\circ_1)]\\ &+\mathbf{j}[S_1S_2(P_2H^\circ_3 - P_3H^\circ_2) + S_2^2(P_3H^\circ_1 - P_1H^\circ_3) + S_2S_3(P_1H^\circ_2 - P_2H^\circ_1)]\\ &+\mathbf{k}[S_1S_3(P_2H^\circ_3 - P_3H^\circ_2) + S_2S_3(P_3H^\circ_1 - P_1H^\circ_3) + S_3^2(P_1H^\circ_2 - P_2H^\circ_1)]\}. \quad (24)\end{aligned}$$

$$\begin{aligned}-\nabla\cdot\nabla(\Psi\cdot\mathbf{P}) = &+\omega^2\{\mathbf{i}[(S_1^2+S_2^2+S_3^2)P_3H^\circ_3 - (S_1^2+S_2^2+S_3^2)P_3H^\circ_2]\\ &+\mathbf{j}[(S_1^2+S_2^2+S_3^2)P_3H^\circ_1 - (S_1^2+S_2^2+S_3^2)P_1H^\circ_3]\\ &+\mathbf{k}[(S_1^2+S_2^2+S_3^2)P_1H^\circ_2 - (S_1^2+S_2^2+S_3^2)P_2H^\circ_1]\}. \quad (25)\end{aligned}$$

Through the utilization of the above expressions, three scalar equations, each of the type (26) are obtained. The running index q goes cyclically 1, 2, 3. Thus the subscripts q, $q+1$, $q+2$ become

equation	q	$q+1$	$q+2$
1st	1	2	3
2nd	2	3	1
3rd	3	1	2.

$$\begin{aligned}P_q[a(S_{q+1}^2+S_{q+2}^2-1/c^2)+b(S_qS_{q+1}H^o_{q+2}-S_qS_{q+2}H^o_{q+1})-1/c^2]\\ +P_{q+1}[bH^o_{q+2}(S_{q+1}^2+S_{q+2}^2-1/c^2)-aS_qS_{q+1}+bS_qS_{q+2}H^o_q]\\ +P_{q+2}[-bH^o_{q+1}(S_{q+1}^2+S_{q+2}^2-1/c^2)-aS_qS_{q+2}-bS_qS_{q+1}H^o_q]=0. \quad (26)\end{aligned}$$

Use will also be made of the definitive relationships

$$\begin{cases}S'^2 \equiv S_1^2+S_2^2+S_3^2-1/c^2 \equiv S^2-1/c^2,\\ A_q \equiv a(S'^2-S_q^2)+bS_q(S_{q+1}H^o_{q+2}-S_{q+2}H^o_{q+1})-1/c^2,\\ B_q \equiv bH^o_{q+2}(S'^2-S_q^2)+S_q(-aS_{q+1}+bS_{q+2}H^o_q),\\ C_q \equiv bH^o_{q+1}(S'^2-S_q^2)+S_q(aS_{q+2}+bS_{q+1}H^o_q). \end{cases} \quad (27)$$

Each equation containing the running index q consists of three equations as indicated above. Employing (26) and (27) together with the preceding identities, (20) simplifies to

$$\left.\begin{aligned}A_1P_1+B_1P_2-C_1P_3=0,\\ -C_2P_1+A_2P_2+B_2P_3=0,\\ B_3P_1-C_3P_2+A_3P_3=0.\end{aligned}\right\} \quad (28)$$

A non-trivial solution of (28) is obtained only when its determinant $=0$. Thus

$$\left.\begin{aligned}P_2=P_1(C_1C_2-A_1B_2)/(B_1B_2+A_2C_1),\\ P_3=P_1(A_1A_2+B_1C_2)/(B_1B_2+A_2C_1)\end{aligned}\right\} \quad (29)$$

and

$$A_1A_2A_3+B_1B_2B_3-C_1C_2C_3+A_1B_2C_3+A_2B_3C_1+A_3B_1C_2=0. \quad (30)$$

It is readily seen that, after a few manipulations, (30) reduces to

$$\begin{aligned}J(S'^2-S_1^2)(S'^2-S_2^2)(S'^2-S_3^2)+K(S'^2-S_1^2)(S'^2-S_3^2)\\ +L(S'^2-S_1^2)(S'^2-S_2^2)+M(S'^2-S_2^2)(S'^2-S_3^2)\\ +N(S'^2-S_1^2)+P(S'^2-S_2^2)+Q(S'^2-S_3^2)+R=0, \quad (31)\end{aligned}$$

where the coefficients of the terms involving S, that is, J, K, L, M, N,

P, Q, R are given by

$$J = a^3 + ab^2H^{o2}, \tag{32}$$

$$\left.\begin{aligned} K &= -(1/c^2)(a^2 + b^2H^{o}_{2}{}^2), \\ L &= -(1/c^2)(a^2 + b^2H^{o}_{3}{}^2), \\ M &= -(1/c^2)(a^2 + b^2H^{o}_{1}{}^2), \end{aligned}\right\} \tag{33}$$

$$\left.\begin{aligned} N &= -aS_2{}^2S_3{}^2(a^2 + b^2H^{o2}) - (1/c^2)(2b^2S_2S_3H^{o}_{2}H^{o}_{3}) + a/c^4, \\ P &= -aS_1{}^2S_3{}^2(a^2 + b^2H^{o2}) - (1/c^2)(2b^2S_1S_3H^{o}_{1}H^{o}_{3}) + a/c^4, \\ Q &= -aS_1{}^2S_2{}^2(a^2 + b^2H^{o2}) - (1/c^2)(2b^2S_1S_2H^{o}_{1}H^{o}_{2}) + a/c^4, \end{aligned}\right\} \tag{34}$$

$$\begin{aligned} R = &-2aS_1{}^2S_2{}^2S_3{}^2(a^2 + b^2H^{o2}) \\ &-(1/c^2)[2b^2S_1S_2S_3(S_3H^{o}_{1}H^{o}_{2} + S_2H^{o}_{1}H^{o}_{3} + S_1H^{o}_{2}H^{o}_{3}) \\ &\quad - b^2(S_2{}^2S_3{}^2H^{o}_{1}{}^2 + S_1{}^2S_3{}^2H^{o}_{2}{}^2 + S_1{}^2S_2{}^2H^{o}_{3}{}^2) \\ &\quad\quad - a^2(S_1{}^2S_2{}^2 + S_1{}^2S_3{}^2 + S_2{}^2S_3{}^2)] - (1/c^6). \end{aligned} \tag{35}$$

At this point the various factors involving S_q may be expanded and the resulting equation then reduced to a quartic in $(cS_q)^4$. Considering the case where $q = 1$,

$$\alpha(cS_1)^4 + \beta(cS_1)^3 + \gamma(cS_1)^2 + \delta(cS_1) + \epsilon = 0, \tag{36}$$

where

$$\alpha = a^2(a+1) + ab^2H^{o2} + b^2H^{o}_{1}{}^2, \tag{37}$$

$$\beta = 2b^2c(S_2H^{o}_{2} + S_3H^{o}_{3})H^{o}_{1}, \tag{38}$$

$$\begin{aligned} \gamma = c^2(S_2{}^2 + S_3{}^2)[2a(1+a) + 2ab^2H^{o2} + b^2H^{o}_{1}{}^2] + b^2c^2(S_2H^{o}_{2} + S_3H^{o}_{3})^2 \\ - [2a(1+a)^2 + (1+2a)b^2H^{o2} + b^2H^{o}_{1}{}^2], \end{aligned} \tag{39}$$

$$\delta = 2b^2cH^{o}_{1}(S_2H^{o}_{2} + S_3H^{o}_{3})[c^2(S_2{}^2 + S_3{}^2) - 1], \tag{40}$$

$$\begin{aligned} \epsilon = c^4\{(S_2{}^2 + S_3{}^2)^2[a^2(1+a) + ab^2H^{o2}] + b^2(S_2{}^2 + S_3{}^2)(S_2H^{o}_{2} + S_3H^{o}_{3})^2\} \\ - c^2\{(S_2{}^2 + S_3{}^2)[2a(1+a)^2 + (1+2a)b^2H^{o2}] + b^2(S_2H^{o}_{2} + S_3H^{o}_{3})^2\} \\ + (1+a)^3 + (1+a)b^2H^{o2}. \end{aligned} \tag{41}$$

COMPARISON OF RESULTS WITH APPLETON'S AND BOOKER'S RELATIONSHIPS.

To establish the identity of (36) with the corresponding equation of Appleton (2), assume that the restitutive term in (7) is non-existent, that is, that we deal with an electron gas, and that the damping term arises solely from collisional friction between the electrons and other particles. Further, let $S_3 = S_2 = 0$, whence (36) assumes the form

$$A(cS_1)^4 + B(cS_1)^2 + C = 0 \tag{42}$$

or in Appleton's notation

$$A'(c^2S_1^2 - 1)^2 + B'(c^2S_1^2 - 1) + C' = 0, \tag{43}$$

where

$$\begin{aligned} A' &= A, \\ B' &= 2A + B, \\ C' &= A + B + C \end{aligned}$$

and

$$\left.\begin{aligned} A &= a^2(1 + a) + ab^2H^{o2} + b^2H^{o}{}_1^2, \\ B &= -\left[2a(1 + a)^2 + b^2H^{o}{}_1^2 + b^2H^{o2}(1 + 2a)\right], \\ C &= (1 + a)^3 + (1 + a)b^2H^{o2}. \end{aligned}\right\} \tag{44}$$

When $H^{o}{}_2 = 0$, (43) becomes

$$(cS_1)^2 - 1 = 2\left[2a + (b^2H^{o}{}_3{}^2)/(1+a) \pm \sqrt{(bH^{o}{}_3)^4/(1+a)^2 - 4b^2H^{o}{}_1{}^2}\right]^{-1}. \tag{45}$$

Equation 45 is identical with that deduced by Appleton except for one trivial respect. Following Lorentz (8), Appleton employed a wave solution of the type $\mathbf{A}e^{i\omega(t-\mathbf{S}\cdot\tau)}$ whereas in this presentation a wave solution $\mathbf{A}e^{i\omega(\mathbf{S}\cdot\tau-t)}$ was utilized (9). Obviously the choice between the two is wholly arbitrary. The results differ only in the algebraic sign of the imaginary terms.

The reduction of (36) to Booker's equation is similarly obtained. When $S_3 = 0$, (36) becomes

$$A(cS_1)^4 + B(cS_1)^3 + C(cS_1)^2 + D(cS_1) + E = 0, \tag{46}$$

where

$$\begin{aligned} A &= a^2(1 + a) + ab^2H^{o2} + b^2H^{o}{}_1^2, \\ B &= 2b^2cS_2H^{o}{}_1H^{o}{}_2, \\ C &= c^2S_2^2\left[2a^2(1 + a) + 2ab^2H^{o2} + b^2H^{o}{}_2^2 + b^2H^{o}{}_1^2\right] \\ &\qquad - \left[2a(1 + a)^2 + (1 + 2a)b^2H^{o2} + b^2H^{o}{}_1^2\right], \\ D &= 2b^2cS_2H^{o}{}_1H^{o}{}_2(c^2S_2^2 - 1), \\ E &= c^4S_2^4\left[a^2(1 + a) + ab^2H^{o2} + b^2H^{o}{}_2^2\right] \\ &\qquad - c^2S_2^2\left[2a(1 + a)^2 + (1 + 2a)b^2H^{o2} + b^2H^{o}{}_2^2\right] \\ &\qquad + (1 + a)^3 + (1 + a)b^2H^{o2}. \end{aligned}$$

Multiply (46) by the factor $-(N^2e^6/m^3\omega^6)$. Neglect the polarization term $(Ne^2/3m)$ and the restitutive force term (involving k).

Define the following equalities

$$\begin{aligned} u &= 1 - il/\omega, \\ x &= Ne^2/m\omega^2, \\ \mathbf{y} &= e\mathbf{H}^{o}/mc\omega, \\ cS_2 &= \sin\theta. \end{aligned}$$

Employing these relationships, the coefficients of (cS_1) in (46) become

$$\left.\begin{aligned} A &= u^3 - xu^2 - uy^2 + xy_1^2, \\ B &= 2xy_1y_2\,(\sin\theta), \\ C &= 2u(y^2\cos^2\theta - u^2\cos^2\theta + xu\cos^2\theta + xu - x^2) \\ &\quad - xy_1^2(\cos^2\theta + 1) - xy_2^2\cos^2\theta + xy_3^2, \\ D &= -2xy_1y_2\sin\theta\cos^2\theta, \\ E &= (u - x)[(u\cos^2\theta - x)^2 - y_2^2\cos^4\theta] \\ &\quad - \cos^2\theta(y_1^2 + y_3^2)(u\cos^2\theta - x). \end{aligned}\right\} \tag{49}$$

Equation 46 with the coefficients (49) is Booker's relationship for the index of refraction when wave packets impinge obliquely upon a stratified doubly refracting ionosphere. Note that he also employed a

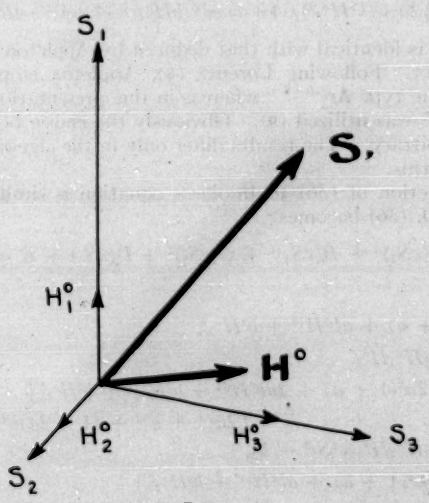

FIG. 1.

wave solution $\mathbf{A}e^{i\omega(t-\mathbf{S}\cdot\tau)}$ and that therefore the signs of the imaginaries in (49) are negative with respect to those which he obtained.

From the above comparison, it would appear that both Appleton, Booker, and others considered an ionosphere which was essentially homogeneous and isotropic. Components of the vectors **S** and $\mathbf{H}^\circ$ are depicted in Fig. 1.

The preceding development is perfectly general. The results may be applied to the ionosphere under the assumption that this region is homogeneous and isotropic and that no forces of interaction other than restitutive, damping or accelerating forces on the electrons appear.

Some workers have applied Eq. 36 to the atmosphere's ionized strata under the restrictions that S_2, S_3, H^e_2, etc. = 0.

The significance of the components S_2 and S_3 may be readily seen from the following brief exposition.

To a first approximation the earth and its ionosphere will be considered as a sphere and its concentric spherical shell, respectively. Under this simplification, refraction in the ionosphere occurs in accordance with the spherical rather than with the plane form of Snell's Law. Snell's Law for spherical surfaces is (see Fig. 2)

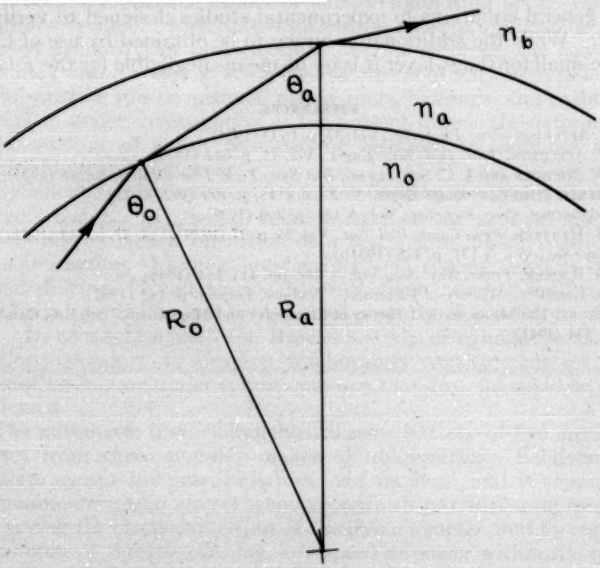

FIG. 2.

$$n_o R_o \sin \theta_o = n_a R_a \sin \theta_a = \cdots = n_r R_r \sin \theta_r. \tag{50}$$

In ionospheric studies an important factor is the maximum height of penetration, that is, the height at which R_r of Eq. 50 is the hypotenuse of a right triangle. At this height, with little error, $\theta_r = \pi/2$; a reasonable assumption since $R_{r-1} \cong R_r$. Assume also that n_o = unity immediately below the base of the ionosphere. Thus, at the maximum height

$$\left.\begin{aligned}(R_o/R_2) \sin \theta_2 &= n_2 = cS_2,\\ (R_o/R_3) \sin \theta_3 &= n_3 = cS_3,\end{aligned}\right\} \tag{51}$$

where

R_e = distance from center of spherical earth to the base of the ionosphere,

$R_2(R_3)$ = distance from center of spherical earth to maximum height of the components $S_2(S_3)$,

$\theta_2(\theta_3)$ = angle of incidence on ionosphere of wave component having reciprocal velocity $S_2(S_3)$.

Note that in general $R_2 \neq R_3$.

This last consideration appears an important one in any application of the general equations to experimental studies designed to verify the theory. While the additional accuracy to be obtained by use of Eq. 51 may be small for the E-layer it is by no means negligible for the F-layers.

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NOTES FROM THE NATIONAL BUREAU OF STANDARDS.[1]

LABORATORY FOR STUDY OF CYLINDER WEAR.

A new laboratory for the study of automotive engine performance has been installed at the National Bureau of Standards under the direction of A. R. Pierce. Equipped with completely automatic controls, this laboratory offers a means of closely simulating actual operating conditions in such a way that tests can be reliably duplicated. While designed primarily for investigations of cylinder wear, the new equipment may also be used in studying the effects of various types of fuels and lubricating oils on pistons, piston rings, bearings, and carburetors. A problem under investigation at the present time is the determination of the amount of sulfur that can be tolerated in gasolines without appreciably increasing wear.

Cylinder wear is an important factor limiting the useful life of automotive engines. In general, reliable data on the process can be obtained only by actual operation of a test engine under conditions of frequent starting, stopping, accelerating, and cooling, such as occur in normal driving. Road testing has not given reliable results in this work because it is impossible to control properly all conditions of operation. In connection with the Bureau's study of cylinder wear, it was therefore necessary to develop a laboratory arrangement for testing automotive engines under conditions such that any run could be exactly duplicated.

The automatic test equipment utilizes a battery of five automotive engines from three popular makes of automobiles. Each engine is complete except for fans, radiators, and mufflers, and is coupled to a "dynamometer' —an electric generator which provides a uniform load. By varying the electrical output of the dynamometer, and by regulating the amount of throttle opening, any speed or power within the range of the engine may be obtained. The extent of cylinder wear is determined by use of the McKee Wear Gage,[2] which employs a sensitive indentation method developed at the National Bureau of Standards for investigations of the wear of walls and pistons of internal combustion engines.

To obtain data that are valid for actual service, the engines, under the control of a master clock, are put through an operating cycle which provides conditions corresponding to cold starting, warm-up, speed-up, idling, stopping, and cooling. The half-hour cycle that is used begins with cold starting, after which the engines are first idled for 1½ min. at 500 rpm., then accelerated for 3½ min. at a speed equivalent

[1] Communicated by the Director.

[2] *NBS Technical News Bulletin*, Vol. 31, No. 7 (July, 1947).

to 40 miles per hour on the road and a horsepower output equal to "road load." The idle and speed-up periods are then repeated three times. At the end of the fourth speed-up period the engines are stopped, and during the remaining 10 min. of the cycle they are artificially cooled to the original starting temperature in preparation for another cold start. The cycle can be repeated automatically as many times as desired.

A wear test requires many comparison runs. In order that data from successive runs may be comparable, the engine temperature, load, and speed must be accurately controlled. Studies at the National Bureau of Standards have shown that both starting and running temperatures have an important effect on cylinder wear. For example, it was determined that a greater amount of wear occurs when the engine is operated at temperatures lower than normal. The temperature reached during the cooling period was found to be most important, as wear was doubled when shutdown temperature was dropped 10° F. in the region near freezing. Temperature must therefore be carefully regulated in order that results obtained with different fuels may be comparable.

Maintenance of standard conditions also requires proper control of load. If the power output were not constant, the fuel consumption would vary, causing a changing temperature within the combustion chamber. Obviously, speed must also be controlled in wear tests in order that each engine may run approximately the same number of revolutions and thus have the same amount of piston travel.

As the engines are not equipped with radiators and fans, proper cooling is obtained during normal operation by means of the engine water pump, which circulates water through the water jacket and into a stand pipe, from which it is returned to the pump. Whenever the temperature of the water exceeds the normal operating temperature, an adjustable thermostat in the pipe line automatically opens a hydraulically operated valve, admitting sufficient tap water to maintain the desired temperature, while the excess passes into the drain.

At the end of the operating period, tap water is first circulated through each engine and through a coil in the oil pan to remove most of the heat. Further cooling to the cold-starting temperature is then accomplished with water artificially cooled to 50° F. Two cold-water tanks are used for this purpose. One is an ice-water tank containing water a few degrees above freezing. It is equipped with a refrigeration coil, and a circulating pump to prevent excessive icing around the coils. The second tank contains a supply of cold water for circulation. Ice water from the first tank is pumped into this tank as needed to maintain the circulating water at the required temperature. The temperature of the cooling water at all times is shown on a 24-hour recording thermograph.

AUTOMATIC CONTROLS.

To permit simultaneous cyclical operation of the five test engines, a central panel for automatic timing and control has been installed. The timing device is basically an electric clock which makes contacts at five-minute intervals, opening and closing circuits to the relay panel at the proper time. The relay panel, in turn, opens, closes, or holds the circuits that operate the throttle, the cooling system, the starter, and the stopping mechanism. Five indicating lights on the panel show what part of the cycle is in progress, thus permitting a ready check on the compliance of the engines with the controls. From this central panel any cycle of operations may be arranged.

In addition, each engine has an individual control panel which contains a recording vacuum gage, an oil-pressure gage, temperature indicators for water and oil, tachometers to show the speed of the engines, and switches for each type of operation. Any engine may thus be cut out of the test cycle and controlled manually during adjustment or repair. This arrangement also permits an engine to be stopped, if necessary, for observation without interfering with the others that are running on the cycle.

In order that corresponding valves for all engines may be operated simultaneously, electric solenoid valves are used. For similar reasons, the throttles are provided with electric solenoids. During the speed run the throttles are held by a spring against a stop adjusted to a definite setting; during the idling period the solenoid closes the throttle and holds it in this position.

Each engine is equipped with an automatic choke to insure starting after the cooling period, and also with a device which automatically engages the starter at the beginning of the cycle, or whenever the engine may stop running. Intake manifold pressures of each engine are recorded over a 24-hr. period by a recording gage. Since the manifold vacuum at a given speed is a function of throttle opening, the operation of the engine is thus charted during the cycle, showing periods of starting, stopping, idling, and speeding.

Installation of an automatic multiple thermograph to record continuously the temperatures of all engines is planned. When this has been done, tests will proceed without the intervention of an operator. After the engines, the refrigeration, and the clock have been turned on, the central control panel will take over the operation of the test cycle, repeating the cycle until the test is stopped. At the conclusion of each 24-hr. period, the temperature chart will show the temperatures of the engines and cooling water, and the charts from the manifold gage will show engine performance.

NEW MOTION PICTURE ON DENTAL AMALGAM RELEASED.

A new motion picture in color, entitled "Dental Amalgam—Failures Caused by Moisture Contamination," has just been completed at the National Bureau of Standards. This film, prepared under the joint auspices of the Bureau and the Research Commission of the American Dental Association, is the second of a series of technical films prepared for dental and allied professions.

The dental amalgam film demonstrates one of the most common causes of amalgam failure—namely, contamination with moisture. This contamination with moisture is usually produced by mixing amalgam in the palm of the hand and by condensing amalgam in a wet field. The moisture introduced into the amalgam reacts with the alloy to produce hydrogen gas which causes excessive expansion, lowers compressive strength, and forms blisters. Clinically, contamination of amalgam with moisture is evidenced by expansion causing post operative pain, extrusion of the alloy from the cavity, formation of blisters, faulty margins, and fractured restorations. The film describes a satisfactory technique for the prevention of contamination.

Since 1928 the National Bureau of Standards and the American Dental Association have conducted cooperative research on the physical and chemical properties of dental materials and the proper techniques involved in their use. The present film, the second of a series that will stress the clinical significance of the physical and chemical properties of dental materials and the importance of technique, is a result of this research. The first film, "Silicate Cement," was made available to the dental profession last fall.

The new motion picture on amalgam, a 16-mm. sound film photographed in color, has a running time of 15 min. The film is available from the NBC: loan or purchase information can be obtained by writing to the Office of Scientific Publications, National Bureau of Standards, Washington 25, D. C. The heavy demands for the silicate cement film suggest that the amalgam film will also be heavily booked: it is therefore advisable that loan requests be made at least 30 days in advance of any projected showing.

A RADIO-FREQUENCY MASS SPECTROMETER.

A comprehensive investigation of the conditions for the formation of negative atomic ions of the heavier metallic elements has led to the development, by Dr. Willard H. Bennett of the National Bureau of Standards, of an extremely valuable method for detecting, separating, identifying, and measuring such ions—one of the most neglected fields of research in pure physics. Since negative atomic ions, consisting of atoms with extra electrons, have very low energies of formation, their

study has been difficult because of the rapid dissociation of the ions in very short distances of travel; that is, before they can reach a measuring electrode. The exacting requirements of this field of research have now been met by means of a specially designed vacuum tube which provides a greatly simplified and flexible radio-frequency mass spectrometer. This spectrometer not only opens up a new means of exploring the little-known fundamentals of negative atomic ions but its special characteristics make it widely applicable for other uses, including the mass spectrometry of positive ions.

Negative atomic ions have been detected for only a few elements since they were first discovered about 40 years ago, although accepted theory has indicated the possibility of producing such ions from many of the elements. Experiments begun at the National Bureau of Standards by Dr. Bennett in 1946 indicated that negative atomic ions might well exist in the many familiar forms of electrical discharge in vacuum tubes, but that they would not be detected if the distance through the tube between the discharge and the electrode was large. It was necessary, therefore, to devise an experimental method for separating and identifying such ions within distances of only a few centimeters. This was accomplished through the new mass spectrometer tube.

In its more advanced form, this two-stage spectrometer may be used for positive ions as well as negative ions. The equipment consists essentially of a multigrid tube in which an adjustable radio frequency is applied to two grids while all other electrodes are held at the proper direct-current potentials, and the ion current is measured at the plate. The more exacting requirements of negative-ion separation require the use of a small magnetic field produced with coils, but if positive ions are being separated, no magnetic field is needed. Because large electromagnets or tubes containing electrodes with elaborate slit systems are not required in this method, the radio-frequency mass spectrometer should find wide application where its resolution is sufficient and where the expense of the more elaborate, conventional beam-deflection equipment is not justified.

One of the principal limitations upon the resolution possible with the ordinary mass spectrometers using magnetic deflection of beams has been the spread in energies of the ions at the ion source. The percentage spread occasioned by this factor can be reduced by increasing the voltage applied to the ions before they are magnetically resolved. The extent to which this can be done is limited, however, by the magnetic field that can be obtained in a space sufficient to contain the tube.

In the radio-frequency mass spectrometer, this difficulty is eliminated, and the voltage of the ions can easily be pushed up at least an additional order of magnitude to any value for which insulation can be provided. The frequencies required are then increased by an amount equal to the square root of the factor by which the voltage is increased.

Raising the voltage from 100 to 10,000 v., for example, increases the frequencies ten-fold, and reduces the percentage spread of mass line due to velocity spread in the ion sources by a factor of one one-hundredth.

The first successful radio-frequency mass spectrometer, a single-stage six-electrode tube, consists of a cathode about which are arranged four co-axial cylindrical grids and an ion-collecting plate. Helmholtz coils surrounding the tube provide a 100-gauss magnetic field in a direction parallel with the axis of the tube. Such a field is required in negative-ion work to confine the electrons to the space inside the first grid and to avoid the formation of positive ions in parts of the tube where neutralization of the negative ions may occur before they reach the detecting electrode.

In the operation of the single-stage negative-ion spectrometer tube, ions arising at the cathode are accelerated through the first grid at a velocity corresponding to the d-c. potential of that grid (say 15 v.). They are further accelerated by the field due to the potential on the second grid which is an alternating radio frequency (say 5 v.) plus a d-c. potential (reduced to 10 v.). The third grid is held at a d-c. potential (reduced to 5 v.). Those ions which pass the first grid at the proper phase of the r-f. field, and which have a mass and related velocity such that they pass through the second grid while the r-f. potential changes phase, receive an additional acceleration due to the r-f. field while travelling to the third grid. It was found experimentally, verifying theoretical calculation, that ions passing the first grid at 45°27.5′ of phase angle of the alternating current on the second grid, and having just the right mass (and corresponding velocity) to pass the second grid at 180° of phase angle of the current on that grid, will pass each of the first three grids with the same velocity (corresponding to 15 v.), although the d-c. potentials on those grids are successively reduced. This is caused by the ion picking up energy from the field of the alternating current on the second grid since the change in phase occurs as the ion passes through this grid.

A blocking potential difference, nearly equal to the maximum energy which an ion with the proper mass (corresponding to the frequency) could pick up from the alternating current, is applied between the cathode and the fourth grid. The blocking potential may be, for example, 9.6 v. negative with respect to the cathode. The collecting electrode, or ion-collection plate, is held at 40 v. positive with respect to the cathode to insure that no positive ions will reach the anode. An electrometer tube circuit and galvanometer are used for measuring the selected ion currents to the anode.

By observing the negative atomic ions produced at an oxide-coated cathode in a water-vapor atmosphere at less than 10^{-6} mm. of mercury pressure, typical mass-resolution data may be obtained for plotting resolution curves. The data are taken while holding all potentials con-

stant and varying only the applied radio frequency. For example, an a-c. potential of 5 v. may be used while d-c. potentials of less than 100 v. are applied to the other electrodes. The required frequency range extends from 3300 kilocycles for a mass value of ¼, to 104 kilocycles for mass value 250. This range of readily producible radio frequencies more than covers the full mass range of all elements.

By extending the method to two stages in a nine-electrode tube, either with cylindrical or parallel-plane electrodes, and applying the radio frequency to two of the grids, a high order of mass resolution is obtained. Such a large number of grids would not be practical in a tube if the usual woven-wire screens were used. There is available now, however, a knitted wire fabric which has more than 95 per cent open area and with which this kind of tube can readily be constructed. This apparatus may be used in the mass spectrometry of positive ions and in ionizaton studies, as well as in the present negative-ion investigations. The magnetic field is again applied in a direction parallel with the planes of the grids for negative-ion investigations. A collimating electrode containing the cathode is used to direct the ions in a direction approximately normal to the planes of the grids.

In the positive-ion mass-spectrometer tube, the ions, accelerated toward the second grid, are resolved by the application of a radio frequency on the third grid, just as in the single-stage tube. The distance between the fourth and fifth grids is selected to assure that those ions which acquire the maximum energy from the alternating-current fields at the first stage (grids 2, 3, and 4) will travel from grid 3 to grid 6 in the time that the radio frequency takes to traverse an exactly integral number of cycles. The same radio frequency is applied to the sixth grid as to the third grid and the other potentials on the second stage (grids 5, 6, and 7) are selected in a similar manner to those for the first stage. The blocking potential is applied to the anode, and the selected ions are collected there.

The simplicity and low cost of the radio-frequency mass spectrometer should make it attractive not only in those applications in which its special characteristics make it superior to any other kind of mass spectrometer, but also in those laboratories where the expense of other types of equipment is prohibitive. Though the possibilities of the new apparatus have not yet been adequately explored, preliminary experimentation at the National Bureau of Standards indicated that many specilized uses for this kind of tube will come to light as it becomes better known.

Frost Control with Air Circulators (*Weatherwise*, Vol. 1, No. 5).—Wind machines have been used in California for the past ten years to combat frost. On a clear, cool night with active radiation, the temperature at a height of 45 ft. may be 10 degrees warmer than the air 5 ft. above the ground. A wind machine breaks up this stratification of the air and causes vertical mixing of the warm air with the cooler air at fruit level.

The machine consists of a tubular column 30 ft. high, 24 in. in diameter, on top of which are mounted two 100-hp. engines. The propellers, each 11½ ft. long and of solid aluminum alloy, are connected to the engines through a transmission. Each propeller turns at 900 revolutions per minute and moves approximately 300,000 cu. ft. of air per minute at a low velocity, since the blades are set at a very flat pitch.

The tubular column is mounted in a base block of concrete 8 ft. square weighing 8½ tons, reinforced with 350 lb. of steel. The machine is entirely controlled from below, with visual temperature, ammeter, and oil gages. The center column holds 600 gal. of gasoline, which is sufficient for 40 hr. of operation, at a cost of approximately $2.50 per hour.

The distributors state that one machine will protect up to 40 acres of deciduous fruits and up to 20 acres of citrus, depending on the heights of the trees and the density of the foliage. However, the wind machines are of little value in combating a "deep-freeze condition," when polar continental air spills over into the Pacific Coast area, bringing a constant flow of below-freezing air.

Puri-Pulley Magnetic Pulley (*Rubber Age*, Vol. 63, No. 6).—A completely new type of magnetic pulley, known as the "Puri-Pulley," has been produced by the Eriez Mfg. Co., of Erie, Penna. The unit is non-electric and was developed solely to remove fine iron or less magnetic particles and afford automatic separation of ferrous from non-ferrous material ranging in size from ten to two hundred mesh.

While present magnetic pulleys are built to throw a magnetic field out several inches (for the removal of ordinary tramp iron), the Puri-Pulley's strength is concentrated in close to the face plate. At one inch from the pulley's surface, the magnetic field is approximately three times as strong as a standard pulley. Design characteristics, as well as new alnico material, account for additional strength.

The effective cleaning surface has been increased substantially by narrowing the air-gaps and increasing the number of pole plates. This provides more major areas of magnetic concentration, hence better magnetic separation. These features make the unit highly adaptable for removing fines from such materials as talcs, powders, chemicals, salts, glass sands, ball clays, granulated slag, rubber and any other substances requiring a high degree of purification. The effective cleaning range varies depending on the size of material being processed and the type of separation desired.

Designed for use as a head pulley in belt conveying systems, the unit is available in 18- and 24-in. diameters and in belt lengths ranging from 12 to 60 in.

THE FRANKLIN INSTITUTE.

MEDAL DAY PROCEEDINGS.

The annual reception, dinner and presentation of awards, known as "Medal Day," took place at The Franklin Institute on Wednesday, October 20, 1948. The reception began at 6:30 P.M. and dinner was served at 7:15 P.M. Mr. Richard T. Nalle, President of the Institute, presided at the dinner and presented the subsequent awards.

RECEPTION.

The reception preceding the dinner was given by the Hostess Committee of The Franklin Institute, and was attended by 370 persons. It was held in rooms adjoining the Chemistry Section. Dinner was served in Franklin Hall.

Immediately before dinner was served, the National Anthem was played by Mr. Guy Marriner.

REMARKS OF THE PRESIDENT.

MR. NALLE: "Ladies and Gentlemen.

"The Franklin Institute was founded 34 years after Benjamin Franklin's death to perpetuate one of his important interests.

"This was the promotion of the mechanic arts, now broadly manufacture, and the encouragement and education of young engineers and mechanics.

"It is for this reason that it is a part of these Medal Day ceremonies to do him honor. Accordingly, Ladies and Gentlemen, I propose a toast to the memory of Benjamin Franklin."

* * *

MR. NALLE (*continued*): "On behalf of the Board of Managers and the Officers, I welcome you to The Franklin Institute. We are assembled tonight to honor fourteen gentlemen for their achievements in the world of Science and the Arts.

"The Hostess Committee, of which Mrs. John White Geary is Honorary Chairman and Mrs. Pennypacker Chairman, is responsible for the flowers and has helped with the reception. I give them our thanks."

* * *

MR. NALLE (*continued*): "Will the sponsors for the 1948 Recipients of Awards kindly take their places?"

STATED MONTHLY MEETING.

MR. NALLE (*continued*): "This is also the regular stated October meeting of the Institute.

"The minutes of the last regular meeting in May have been published in the June issue of the JOURNAL and, if there are no corrections or additions, I declare them approved as printed.

"It is the custom to elect our Franklin Medalists to Honorary Membership in the Institute, so at the September meeting of the Board of Managers nominations were made to present to the membership at this meeting with the recommendation that they consider favorably the election of Dr. Wendell Meredith Stanley and Dr. Theodor von Kármán to honorary membership in the Institute. Accordingly, will all the members present in favor of such election please say 'Aye'. Contrary minded—.

"Carried. I declare them elected."

* * *

MR. NALLE (*continued*): "It is customary to invite to our Medal Day proceedings the recipients of Awards made in previous years. There are twenty such here tonight and we welcome them. I shall read their names, city, and the Award received and ask that each rise as his name is called and remain standing until the roll is completed. To save time I suggest that you withhold your applause until all are standing.

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FORMER MEDALISTS ATTENDING MEDAL DAY—1948.

Year	Medalist	City	Medal
1904	Clamer, Dr. G. H.	Philadelphia, Pa.	Cresson
1915	Young, General Charles D.	Chester County, Pa.	Longstreth
1918	Creighton, Dr. H. Jermain	Swarthmore, Pa.	Longstreth
1939	Creighton, Dr. H. Jermain	Swarthmore, Pa.	Potts
1920	Leeds, Mr. Morris E.	Philadelphia, Pa.	Longstreth
1921	Adams, Dr. L. H.	Washington, D. C.	Longstreth
1923	Parks, Mr. Harry S.	Pottstown, Pa.	Longstreth
1924	McBride, Mr. Thomas C.	Philadelphia, Pa.	Longstreth
1926	Smathers, Mr. James F.	Poughkeepsie, N. Y.	Longstreth
1930	Moultrop, Mr. Irving E.	Belmont, Mass.	Cresson
1932	Wenner, Dr. Frank	Washington, D. C.	Wetherill
1934	Shryock, Mr. Joseph G.	Philadelphia, Pa.	Certificate of Merit
1937	Eksergian, Dr. Rupen	Philadelphia, Pa.	Henderson
1945	Eksergian, Dr. Rupen	Philadelphia, Pa.	Levy
1939	DeJuhasz, Prof. Kalman J.	State College, Pa.	Levy
1939	Wilford, Mr. E. Burke	Philadelphia, Pa.	Certificate of Merit
1942	Larkin, Mr. Walter	Norristown, Pa.	Certificate of Merit
1944	Ennis, Mr. Joseph B.	New York, N. Y.	Henderson
1945	Ellis, Mr. Greer	New York, N. Y.	Certificate of Merit
1946	Southworth, Dr. George	New York, N. Y.	Levy
1947	Southworth, Dr. George	New York, N. Y.	Ballantine
1946	Barnes, Maj. Gen. G. M.	Philadelphia, Pa.	Cresson
1947	Billner, Mr. Karl P.	Philadelphia, Pa.	Brown

MR. NALLE (*continued*): "The Order of Business calls for a report from the Executive Vice President and Secretary of the Institute, Dr. Henry Butler Allen. Dr. Allen, will you present your report, please?"

REPORT OF THE SECRETARY.

"The Institute in 1948."

DR. ALLEN: "Mr. President, Honored Guests, Friends of the Institute, Again this year I am briefly going to run through the several activities of our Franklin Institute. We have some new faces here tonight and we want them to know what the Institute does, and our Medalists constitute a part of our alumni, even though they did not go to school here. We really did have school, by the way, which ran for 99 years.

"One of the Institute's strong points through the years has been its willingness to relinquish activities and to undertake new forms of service as times change; but always in its chartered field—physical science.

"Following this policy our former evening school enterprise was replaced by the establishment, 15 years ago, of a modern science Museum—visual education for the old and young. Incidentally, our Museum opens to the public on the twenty-ninth of this month for a three months' stay, an extensive Atomic Energy Exhibit from the Brookhaven Atomic Energy Laboratories—a FIRST for Philadelphia.

"Our technical and patent libraries continue to serve the manufacturer, research worker and student, as do our Lectures and our Journal, all of which activities were started *circa* 1824.

"Research is growing in The Franklin Institute to the extent of having today the largest staff of any department in the Institute. So-called pure research centers primarily in our Bartol Research Foundation started 34 years ago, where a force of fifty-five people contribute to the increase of knowledge about cosmic rays and other atomic particles, as well as other physical phenomena. Our more recent laboratories for industrial research now employ a staff of some three hundred persons. Manufacturers are finding our services increasingly useful. We have a particularly powerful tool for their problems through the combination of the brains of a pure research foundation and those of an applied science laboratory, superimposed upon the background of the Institute.

"One of our newest babies was born with the unveiling of our statue in this Hall ten years ago, namely, the reincarnation of Benjamin Franklin with the dissemination of his sound teachings about citizenship, science, and service to his fellow man. We are called upon from all over the country, and overseas, for information about him. We have evidence that this service has perhaps been not unhelpful in giving some a better understanding of our form of government, as well as what consti-

tutes a useful citizen of our country and the world. This activity under our National Franklin Committee has shown within the last year a curiously tangible consequence that I know would intrigue our Patron Saint. It certainly pleased us. What happened was this: We had a call from a gentleman from a mid-west city, who had seen some of our Franklin pamphlets. He was coming east, and wanted to stop in for more information. He was giving a talk to a group of young people, about Franklin. He came, and in conversation learned that we had research laboratories. He suggested that we get in touch with a Foundation in his home city, the benefactor of which was a personal friend of his. We wrote this Foundation that we needed support on a certain research project, not of interest to any one industry. To make a long story short, the Foundation gave us very substantial financial aid.

"President Nalle has already spoken about our other century-old activity—Medal Awards. He did not tell you, however, that this year marks the 100th anniversary of one of our medals, the Elliott Cresson, and that his great uncle was among the first group of individuals to receive this award for development of the "Sand Blast"—Benjamin C. Tilghman.

"That, ladies and gentlemen, is a brief outline of The Franklin Institute's present-day activities. We hope that you will visit us often, learn more about us, and perhaps help us become even more useful to our public."

MR. NALLE: "Over the years, and next year will be our 125th Anniversary, fourteen medals have been established through the generosity of members. These medals are awarded for outstanding accomplishment in various scientific fields in accordance with the terms of the gift.

"Some 1050 medals have been awarded to date. The recipients have been of many nationalities, the coverage has been world-wide. In the last 20 years, twenty-one medals have gone to England, ten to Germany, six to Sweden, five to France, and thirteen to ten other countries.

"A Committee of the Institute, the Committee on Science and the Arts, is charged with the selection of the candidates. It is their responsibility to search out the worthwhile developments and discoveries which occur in the various sciences, make a thorough investigation of the case and satisfy themselves that the individual concerned has made the requisite personal contribution.

"When the Sub-committee in charge decides that a case is worthy, its findings are reviewed by the whole Committee and, if approved, the recommendation is submitted to the Board of Managers for final approval. If all goes well, the individual joins in our Medal Day exercises and receives the particular Medal applicable to his work.

"Each Medalist is sponsored by the Chairman of the Sub-committee

that recommends him for the Award. The Sponsor makes a brief statement as to the nature of the Medalist's work and the citation.

"We regret that two of our Medalists could not be with us tonight. Dr. von Kármán is detained in Europe and Dr. Colpitts is in the hospital with an operation that could not be delayed. Their Medals will be sent to them by the Secretary.

"We will now proceed to the presentation of the Awards."

Mr. Nalle then called upon the sponsors to present their candidates for the awards.

PRESENTATION OF THE ELLIOTT CRESSON MEDAL.

(To Edwin H. Colpitts, Orange, New Jersey, Director, The Engineering Foundation, New York 18, N. Y.)

MR. NALLE: "I recognize Dr. Winthrop R. Wright, the sponsor of Dr. Edwin H. Colpitts, who will receive the Cresson Medal *in absentia*. Dr. Wright.

DR. WRIGHT: "Mr. President, I present, *in absentia*, Edwin H. Colpitts for an award.

"The phenomenal growth of the world's communication networks since the turn of the century is one of the miracles of the twentieth century. Our Medalist has played an outstanding role in this development between the years 1899, when he joined the American Bell Telephone Company in Boston, and 1937, when he retired as vice-president of the Bell Telephone Laboratories with 24 United States patents to his credit. He was directly responsible for the experimental work undertaken to verify the theoretical work of George A. Cambell on the loaded telephone line. The oscillator circuit bearing our Medalist's name is a classic and known to all communication engineers and students.

"I present, *in absentia*, Edwin H. Colpitts, of Orange, New Jersey, as a candidate for an Elliott Cresson Medal, awarded to him 'In consideration of his pioneering achievements leading to the development of practical systems of long distance communication, both by wire and radio.'"

MR. NALLE: "By virtue of the power vested in me as President of The Franklin Institute of the State of Pennsylvania, I present to Dr. Edwin H. Colpitts, *in absentia*, this Elliott Cresson Medal and the Certificate and Report which accompany it. Dr. Allen, as Secretary of The Franklin Institute, will you see that this Medal and the Certificate and Report which accompany it are transmitted to Dr. Colpitts?"

DR. ALLEN: "Yes, indeed."

PRESENTATION OF THE LONGSTRETH MEDALS.

(To Raleigh J. Wise, Dunnellen, New Jersey, Telefax Research Engineer, The Western Union Telegraph Company, New York 13,

N. Y.; Nicholas F. Arone, Switchgear Division Laboratory, General Electric Company, Philadelphia, Pa., and Edwin H. Brink, Assistant Director of Research, Masonite Corporation, Laurel, Mississippi.)

MR. NALLE: "The next Sponsor, Mr. McClarren."

MR. MCCLARREN: "Mr. President, I present Raleigh J. Wise for an Award. He has been largely responsible for inventing and developing a special recording paper for use in facsimile reception of printed or written matter. Developed just prior to World War II, his recording paper, called 'Teledeltos,' was used extensively for recording all kinds of transmitted information such as maps, pictures, coded messages and for instrument records such as the fathometer and others.

"The Western Union Telegraph Company, with which Mr. Wise is associated, makes extensive use of 'Teledeltos' in its business. Special apparatus has been developed by it to expedite and facilitate the sending of messages from place to place. One such machine will automatically transmit and another will receive at a remote location an exact copy of a written message.

"'Teledeltos' has been made available commercially and is used by many concerns for various recording purposes.

"I present Raleigh J. Wise, of Dunnellen, New Jersey, as a candidate for an Edward Longstreth Medal 'In consideration of the development of a dry electrosensitive recording blank which can be stored and handled like ordinary paper with practically no deterioration or change and which can be permanently marked by simple means.'"

MR. NALLE: "Mr. Wise, by the same authority, I present to you an Edward Longstreth Medal, and the Certificate and Report which accompany it."

Mr. Nalle (*continued*): "I recognize Dr. Crampton as the next Sponsor."

DR. CRAMPTON: "Mr. President, I present Edwin H. Brink and Nicholas F. Arone for awards for an achievement of great usefulness that has contributed to the potential conversion of the entire industrial field from oil circuit breakers with their hazards to life and property, to an air device which has only a fraction of the industrial hazard.

"This has been accomplished through patient and successful search for an inorganic, moldable, thermoset, insulating compound embodying the necessary requirements for use in the construction of magne-blast circuit breakers.

"Here, powerful arcs resulting from such causes as lightning and short circuits, are destroyed by being forced into a series of interleaving, insulating barriers made of the new material Phospho-Asbestos developed by the Medalists. This material is a combination of chrysotile asbestos and phosphoric acid.

"I present Edwin H. Brink, Laurel, Mississippi, and Nicholas F.

Arone, of Philadelphia, to each of whom has been awarded an Edward Longstreth Medal 'In consideration of their persistent search and ingenuity, resulting in the discovery of Phospho-Asbestos and in the chemical and productional development of this uniquely useful product.'"

MR. NALLE: "Mr. Arone, by the same authority, I present to you an Edward Longstreth Medal, and the Certificate and Report which accompany it."

"Mr. Brink, likewise, by the same authority, I present to you an Edward Longstreth Medal, and the Certificate and Report which accompany it."

PRESENTATION OF THE POTTS MEDALS.

(To David Bigelow Parkinson, of Maplewood, New Jersey, Research Engineer, Bell Telephone Laboratories, New York 14, N. Y., and Clarence Anding Lovell, of Summit, New Jersey, Switching Research Engineer, Bell Telephone Laboratories, New York 14, N. Y.; and Eugene J. Houdry, of Ardmore, Pennsylvania, Founder, Houdry Process Corporation, Philadelphia 2, Pa.)

MR. NALLE: "I call upon Colonel Ely."

COLONEL ELY: "Mr. President, I present David Bigelow Parkinson and Clarence Anding Lovell for awards.

"These two scientists have always been interested in unusual electrical and mechanical contrivances and since joining the Bell Telephone Laboratories they have devoted their time to developing better devices for use in the Telephone System. As an outgrowth of this, the basic conception of the Electrical Gun Director came to Dr. Parkinson. Dr. Lovell became coordinator of the gun director development which followed. An amazing fact about this development is that men who had no previous experience with a complex Ordnance problem were able to apply the special electrical techniques used in the communications art to the solution of the military problem with a high degree of accuracy.

"I present David Bigelow Parkinson, of Maplewood, New Jersey, and Clarence Anding Lovell, of Summit, New Jersey, to each of whom has been awarded a Howard N. Potts Medal 'In consideration of their combined contributions, both to the theoretical and practical design of the Electrical Gun Director, one of the outstanding pieces of equipment developed during the war period, which development has further contributed largely to the theory and practical application of servo mechanisms and smoothing filters in general.'"

MR. NALLE: "Dr. Parkinson, by the same authority, I present to

you a Howard N. Potts Medal, and the Certificate and Report which accompany it."

"Dr. Lovell, in the same manner, by the same authority, I present to you a Howard N. Potts Medal, and the Certificate and Report which accompany it."

MR. NALLE: "Mr. Masland."

MR. MASLAND: "Mr. President, I present Eugene J. Houdry for an award.

"Every once in awhile, progress is made by recognizing that an exceedingly difficult obstacle is in the way, and then climbing over the obstacle. Such was the case with the catalytic cracking of petroleum. In many catalytic processes, the active life of the catalyst can be measured in months. In catalytic cracking of petroleum, the active life of the catalyst must be measured in minutes.

"Mr. Houdry recognized this obstinate fact which had previoulsy stopped progress in the catalytic cracking of petroleum and set out to climb over the obstacle. He recognized the very short active life of catalysts suitable for cracking petroleum and he designed and built equipment which gave us high octane gasoline in large quantities during the war when we badly needed it; this in spite of the short life of the catalyst.

"I present Eugene J. Houdry, of Ardmore, Pennsylvania, as a candidate for a Howard N. Potts Medal 'In consideration of his leadership in the development of the important process of catalytic cracking of petroleum that bears his name, utilizing known basic chemical and physical facts.'"

MR. NALLE: "Mr. Houdry, by the same authority, I present to you a Howard N. Potts Medal, and the Certificate and Report which accompany it."

PRESENTATION OF THE LEVY MEDALS.

(To Jan A. Rajchman, Research Engineer, RCA Laboratories, Princeton, New Jersey, and William H. Cherry, Physicist, RCA Laboratories, Princeton, New Jersey.)

MR. NALLE: "The Sponsor for the Levy Medal, Dr. Boehne."

DR. BOEHNE: "Mr. President, I present Jan A. Rajchman and William H. Cherry for awards.

"The betatron or induction accelerator contains closed electron orbits which are the longest, longest lived, and most stable orbits known outside of the atoms themselves. In order for large electron energies to be gained, acceleration must take place over long electron paths. The current widespread development of the betatron as a generator of high energy electrons and gamma rays has created need for a compara-

tively detailed knowledge of the electron dynamics of induction acceleration.

"The paper by Rajchman and Cherry entitled, 'The Electron Mechanics of Induction Acceleration,' describes the radial and axial motions of electrons in the betatron by means of a potential function of forces. Previous studies assumed a potential of parabolic variation. The authors' extension of the analysis to non-parabolic regions describes more accurately their observed behavior of conventional instruments, especially when higher voltages of injection are employed. The new points of view presented are applicable to other electronic devices such as the magnetron and various electron optical lens systems of rotational symmetry.

"I present Jan A. Rajchman and William H. Cherry, of Princeton, New Jersey, as candidates, each for a Louis Edward Levy Medal, 'In recognition of their outstanding paper, "The Electron Mechanism of Induction Acceleration," appearing in the April and May 1947 issues of the JOURNAL OF THE FRANKLIN INSTITUTE.'"

MR. NALLE: "Dr. Rajchman, by the same authority, I present to you a Louis E. Levy Medal, and the Certificate and Report which accompany it."

"Mr. Cherry, likewise, by the same authority, I present to you a Louis E. Levy Medal, and the Certificate and Report which accompany it."

PRESENTATION OF THE HENDERSON MEDAL.

(To Charles Duncanson Young, of Whitford, Pennsylvania, Vice President (Retired), The Pennsylvania Railroad Company.)

MR. NALLE: "The next Sponsor, Mr. J. V. B. Duer."

MR. DUER: "Mr. President, I present Charles Duncanson Young for an award.

"Railroad motive power has been developed through the efforts of many able men, working towards the common aim of producing the most efficient, economical, and reliable locomotive for the lowest possible cost.

"Pioneer among motive power units is the steam locomotive, which has been developed to a degree of reliability, economy and effectiveness, as a transportation unit, little dreamed of by the builders of the first locomotives of this type.

"Outstanding among those who have contributed to this result is our Medalist, who, through his ingenuity in developing a method of testing completed locomotives, while stationary on a testing plant, as well as by his inventions and also by making available to railroad engineers, accurate information regarding the performance of locomotives tested, has made possible substantial increases in efficiency and re-

liability and reductions in cost of steam locomotives, thereby producing a more effective transportation unit.

"I present Charles Duncanson Young, of Whitford, Pennsylvania, as a candidate for the George R. Henderson Medal 'In consideration of his contribution to the scientific advancement of the steam locomotive which has resulted in improving the reliability and efficiency and reducing the cost of steam locomotives thereby producing a more effective transportation unit.'"

MR. NALLE: "General Young, by the same authority, I present to you the George R. Henderson Medal, and the Certificate and Report which accompany it."

PRESENTATION OF THE WETHERILL MEDAL.

(To Wendell Frederick Hess, Head, Department of Metallurgical Engineering, Rensselaer Polytechnic Institute, Troy, New York.)

MR. NALLE: "Dr. Adams, will you take the floor?"

DR. ADAMS: "Mr. President, I present Wendell Frederick Hess for an award.

"One feature of Dr. Hess's career is noteworthy. After studying and teaching Electrical Engineering and Physics for several years, he was transferred to the Department of Metallurgical Engineering of which he is now the head, as well as of the Welding Laboratory at the Rensselaer Polytechnic Institute.

"He thus brought into the metallurgical field a rare and much needed knowledge of analytical physics, so essential to the solution of many metallurigcal and welding problems, notably those involving transient heat flow.

"However, he is best known for his contributions to the field of Resistance Welding, where he started a veritable revolution which is still under way. Merely to list the specific contributions would take more time than is here available. His published papers already number more than fifty, and their sum total constitutes by far the largest contribution by any individual to the art and science of Resistance Welding. This work has already been recognized in the award of numerous prizes and several medals.

"I present Wendell Frederick Hess, of Troy, New York, as a candidate for a John Price Wetherill Medal 'In consideration of his outstanding contributions to the Art and Science of Welding, notably in the field of Electric Resistance Welding.'"

MR. NALLE: "Professor Hess, by the same authority, I present to you a John Price Wetherill Medal, and the Certificate and Report which accompany it."

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PRESENTATION OF THE BALLANTINE MEDAL.

(To Ray Davis Kell, Director of Television Research, RCA Laboratories, Princeton, New Jersey.)

MR. NALLE: "Dr. Murray, Sponsor for the Ballantine Medal, is ill and cannot be with us. Mr. William Ellis will act as Sponsor in his place. Mr. Ellis."

MR. ELLIS: "Mr. President, I present Ray D. Kell for an award.

"The word that most people associate with our rapidly growing, present-day television service is: 'Marvelous.' Many refer to television as the newest invention in the communication field. Actually, it is the result of long and painstaking research and invention over a period of more than 20 years.

"In our Medalist we have a noted engineer, who, during *all* of these twenty years, has been researching and inventing, first with the General Electric Company, later with the Radio Corportaion of America, to make possible the clear, sharp pictures that merit the word: 'Marvelous.'

"In World War II it was he who, applying television to guided missiles, enabled the bombardier effectually to keep his target in view as his controlled bomb glided earthward.

"For the last word in home entertainment, we look forward to television in *color*. Under the direction of Mr. Kell, there has already been demonstrated a color system, which, when it emerges from the development stage, will permit the broadcasting of color images, yet will provide usable signals for our present black-and-white receivers. We wish him continued success in this important work.

"I present Ray Davis Kell, of Princeton, New Jersey, as a candidate for the Stuart Ballantine Medal 'In consideration of his outstanding pioneer work in Television; the adaptation of this means of communication to military needs and for his inventive contributions and leadership in the development of Color Television.'"

MR. NALLE: "Mr. Kell, by the same authority, I present to you the Stuart Ballantine Medal, and the Certificate and Report which accompany it."

PRESENTATION OF THE FRANKLIN MEDALS.

(To Wendell Meredith Stanley, Director of the Virus Laboratory, University of California, Berkeley, California; and Theodor von Kármán, Director of Guggenheim Aeronautics Laboratories, California Institute of Technology, Pasadena, California.)

MR. NALLE: "The next Sponsor, Dr. Palmer."

DR. PALMER: "Mr. President, I have the honor to present as a candidate for the Franklin Medal, Wendell Meredith Stanley.

"Such diseases as influenza, infantile paralysis, encephalitis, measles, smallpox, yellow fever, and the common cold, as well as many other diseases of both animals and plants, are caused by a virus. This is an infectious agent so small as to be invisible in an optical microscope but capable of being photographed in an electron microscope. Until a dozen years ago, each of the many kinds of virus then known was generally regarded as a sub-microscopic living organism, yet some authorities inclined toward the view that a virus is an inanimate chemical substance with the peculiar properties of mutation and reproduction in the host.

"When Dr. Stanley joined the Rockefeller Institute for Medical Research, he attacked the virus problem and in less than three years was successful in isolating a crystalline material that possessed all of the properties of the tobacco mosaic virus. Many other viruses have now been isolated in pure form and they all appear to be composed of giant chemical molecules of very complex structure known as nucleoproteins. From his laboratory also came the first information concerning the changes in chemical structure that accompany the mutation of a virus and give rise either to a more virulent strain or to a less virulent one, such as can provide immunity to millions of individuals against the more virulent strains of the same virus.

"During World War II you, Sir, as the result of your intensive study of the influenza virus, developed an effective vaccine by the application of a new method of purification by means of the centrifuge. Through the general use of this vaccine, influenza epidemics of the future should be greatly reduced in intensity or perhaps entirely prevented.

"Hence, Mr. President, 'In recognition of his discovery that a virus can be a nucleoprotein rather than a living organism, thereby establishing a significant turning point in virus research; and also of his development of an effective centrifuge-type influenza vaccine by means of which the intensity of future influenza epidemics may be greatly lessened,' I take pleasure in presenting Wendell Meredith Stanley."

MR. NALLE: "Dr. Stanley, by the same authority, I present to you a Franklin Medal, the Certificate and Report which accompany it, together with the Certificate of Honorary Membership."

MR. NALLE: "I recognize Mr. W. Laurence LePage, the Sponsor of Dr. Theodor von Kármán, who will receive the Franklin Medal *in absentia*. Mr. LePage."

MR. LEPAGE: "Mr. President, I have the honor to present to you, *in absentia*, as a candidate for the highest award made by The Franklin Institute, a man of great distinction in the field of Aeronautics.

"Dr. Theodor von Kármán is probably the outstanding mathematical and physical fundamentalist engaged in aeronautics today. But more than this, Dr. von Kármán is, at the same time, a very practical engineer.

Thus, we find in him a truly remarkable union of qualities as a result of which every new von Kármán discovery, every novel theoretical conception and each basic theorem is reduced to such practical terms as may be understood and employed by any engineer of normal capabilities.

"This remarkable aerodynamicist has been responsible for the establishment of two great aeronautic institutions, the Aeronautical Institute of the University of Aachen and the Guggenheim Aeronautics Laboratory of the California Institute of Technology. His work has covered such a broad mathematical and mechanical field in aerodynamics, aeronautics and theory of air flow, and has been so outstanding in each contribution, that it has been practically impossible to select any one study as foremost. Furthermore, his great success in stimulating, coordinating and supervising the work of others has added appreciably to the depth and breadth of his own contributions.

"Dr. von Kármán, more than any other single individual, is responsible for the development of super-sonic air flow theory and its practical application. He propounded the method of Fourier integrals in the development of super-sonic wing theory, established the mathematical existence of the shock wave in super-sonic air flow and the practical desirability of the swept back plan form for wings of super-sonic aircraft.

"Sir, upon citation which reads: 'In recognition of his outstanding engineering and mathematical achievements, particularly those relating to the development of advanced aerodynamic conceptions which have directly influenced the progress of aeronautical design, and for his unusual leadership whereby some measure of his own genius is constantly instilled in those who work with him.'

"I present to you, *in absentia*, Theodor von Kármán, Director of the Guggenheim Aeronautics Laboratory of the California Institute of Technology as a candidate for the Franklin Medal."

MR. NALLE: "By the same authority, I present to Dr. Theodor von Kármán, *in absentia*, this Franklin Medal, and the Certificate and Report which accompany it, together with the Certificate of Honorary Membership. Dr. Allen, as Secretary of The Franklin Institute, will you see that these are transmitted to Dr. von Kármán?"

DR. ALLEN: "Yes, indeed."

Upon the conclusion of each award, the recipient briefly expressed his appreciation.

MR. NALLE: "Will the Sponsors kindly resume their seats at their respective tables?"

MR. NALLE (*continued*): "It now gives me great pleasure, and we deem it a privilege, to have the opportunity to present Dr. Wendell

Meredith Stanley who will speak to us about 'Recent Advances in Virus Research.'[1] Dr. Stanley."

Mr. Nalle, after Dr. Stanley had read his paper, conveyed to him the thanks of the Institute.

RECIPIENTS OF AWARDS FOR 1948.

Seated (*left to right*): Eugene J. Houdry (Potts); Clarence Anding Lovell (Potts); Wendell Meredith Stanley (Franklin); Charles Duncanson Young (Henderson); William H. Cherry (Levy).

Standing (*left to right*): Raleigh J. Wise (Longstreth); David B. Parkinson (Potts); Ray Davis Kell (Ballantine); Nicholas F. Arone (Longstreth); Edwin H. Brink (Longstreth); Jan A. Rajchman (Levy); Wendell F. Hess (Wetherill).

MR. NALLE: "Dr. Theodor von Kármán, our other Franklin Medalist and speaker, was unable to return from Europe in time to be with us. He has, however, sent to us his paper on 'Progress in Aviation'[2] which he had intended to give. We ask Mr. LePage, his Sponsor, if he will deliver this short address for Dr. von Kármán. Mr. LePage."

The President then thanked Mr. LePage for reading Dr. von Kármán's paper, and dismissed the assembly with a cordial word and declared the meeting adjourned.

[1] See page 445 for "Recent Advances in Virus Research."

[2] See page 451 for "Progress in Aviation."

STATED MONTHLY MEETING, WEDNESDAY, NOVEMBER 17, 1948.

The Stated Monthly Meeting of The Franklin Institute was held November 17th in the Lecture Hall of The Franklin Institute. The President, Mr. Richard T. Nalle, presided and called the meeting to order at 8:15 P.M. There were approximately 100 people present. The President stated that the monthly meeting for October was the annual Medal Day Exercises, and because of the length of the minutes they had not yet appeared in the JOURNAL OF THE FRANKLIN INSTITUTE. Therefore, their approval would not be asked for until a later date.

The President then called upon the Secretary, Dr. Henry B. Allen, to give the report of the Membership and to make any announcements. The report of the Membership for the month of October was presented as:

Honorary	2
Active	41
Associate	21
Student	22

The total Institute Membership as of October 31, 1948 was 5260.

The Secretary reminded the members and friends of the Institute that the Atomic Energy Exhibit was now on display, and would continue on exhibit through January 30, 1949.

The announcement was then made by the Secretary that the "Star of Bethlehem" show would be demonstrated in the Planetarium beginning November 26th through December.

The Secretary then told the audience about the Laboratories for Research and Development, which now boast of approximately 270 personnel.

The President then introduced Dr. V. K. Zworykin of the RCA Laboratories in Princeton, New Jersey. Dr. Zworykin spoke briefly on the origin of electronic aids for the blind and reviewed the early history of the instruments. He said that the work fell into two classes; one using the characteristics of the letter to generate a signal and the other recognizing the letters electrically and producing sound in response. Dr. Zworykin introduced Mr. L. E. Flory who discussed the first category and demonstrated the direct signal method. Mr. Pike was then introduced by Dr. Zworykin, who demonstrated the more complex instrument for aiding the Blind.

At the conclusion of the meeting, Dr. Corner, chairman of the Committee on Sensory Devices at the Carnegie Institution of Washington, D. C., presented to The Franklin Institute for safekeeping this instrument used in the latter demonstration. The President accepted the instrument on behalf of The Franklin Institute.

The meeting was adjourned at 9:30 P.M., with a vote of thanks to the three speakers of the evening.

HENRY B. ALLEN,
Secretary.

MUSEUM NOTES.

FELS PLANETARIUM.

In one of the Gospels we read of a miraculous star which guided the Wise Men to the manger of young Jesus and, very naturally, the mention of a star inspires people to ask astronomers what this object may have been. Quite frankly, no precise answer to this question can be given. The details are much too obscure and there is no other mention of this event in either sacred or secular literature.

Over a period of about a dozen years the staff of the Fels Planetarium have delved into matters astronomical and historical in the attempt to arrive at a concise and satisfactory sug-

gestion concerning this cherished tradition of the Christian faith. This research has involved investigation of the nationality and even the personality of one who could be called a Wise Man, and many translations of the story have been consulted in the attempt to arrive at unadulterated meanings of the words that are used.

The evidence of the astronomers and of the Gospel itself is really quite clear in indicating that the commonly accepted interpretation of a brilliant, blazing star must be in error. But there was something in the sky that, to those who are called the Wise Men, would have been received as an omen of an important event.

During December for the past several years, it has been our custom in the Fels Planetarium to turn time back through almost 2000 years to reproduce the skies for the period preceding and following the birth of Jesus. By combining the Scriptural story with the established historical and cultural background of the period, we are able to arrive at an answer not only to the question of what was the star of Bethlehem, but also to the far more important question of the date of the birth of Jesus. He was born in the spring of the year 6 B.C. according to the interpretation which is used by the astronomers of the Fels Planetarium.

Following the scientific presentation, the traditional story of the Holy Night and of the arrival of the Wise Men in Bethlehem will be told in Scriptural readings, familiar music, tableaux and interpretative lighting effects.

Other special demonstrations are also under consideration, but each month a newly designed presentation of some phase of astronomy is given. For those who want to know how the calendar we now use has come into being, the January, 1949, demonstration is recommended. Those who attend the "Story of the Calendar" showings will also hear a recommendation for an improved calendar which will preserve the best of what we now have and will eliminate the factors which trouble us from year to year. The February demonstration will tell our visitors how to identify and how to increase their enjoyment of the brilliant stars which stud our winter sky. Further plans for the 1949 program in the Fels Planetarium will be announced as they crystallize.

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of Stated Meeting held Wednesday, November 10, 1948.)

HALL OF THE COMMITTEE,
PHILADELPHIA, NOVEMBER 10, 1948.

DR. THOMAS D. COPE, *Acting Chairman*, in the Chair.

The following report was presented for final action:

No. 3191: Work of Arthur M. Young on the Stability of Helicopters.

This report recommended the award of an Edward Longstreth Medal to Arthur M. Young, of Paoli, Pennsylvania, "In recognition of his successful application of flying scale models to test unproven ideas in helicopter flight."

JOHN FRAZER,
Secretary to Committee.

LIBRARY NOTES.

The Committee on Library desires to add to the collections any technical works that members would wish to contribute. Contributions will be gratefully acknowledged and placed in the library. Duplicates received will be transferred to other libraries as gifts of the donor.

Photostat Service. Photostat prints of any material in the collections can be supplied on request. The average cost for a print 9 × 14 inches is thirty-five cents.

The Library and reading room are open on Mondays, Tuesdays, Fridays, and Saturdays from 9 A.M. until 5 P.M., and Wednesdays and Thursdays from 2 P. M. until 10 P.M.

RECENT ADDITIONS.

BIOGRAPHY.

PEPPER, WILLIAM. The Medical Side of Benjamin Franklin. 1911.

BOTANY.

BALY, EDWARD CHARLES CYRIL. Photosynthesis. 1940.
BOYCE, JOHN SHAW. Forest Pathology. Second Edition. 1948.

CHEMISTRY AND CHEMICAL TECHNOLOGY.

BERGMANN, ERNST DAVID. Isomerism and Isomerization. 1948.
EGLOFF, GUSTAV AND HULLA, GEORGE. Alkylation of Alkans. Vol. 1. 1948.
HOUGEN, O. A. AND DODGE, F. W. The Drying of Gases. 1947.
HUNTRESS, ERNEST HAMLIN. The Preparation, Properties, Chemical Behavior and Identification of Organic Chlorine Compounds. 1948.

ELECTRICITY AND ELECTRICAL ENGINEERING.

SMITH, ARTHUR WHITMORE. Electrical Measurements in Theory and Application. Fourth Edition. 1948.
SOLLER, THEODORE; STARR, MERLE A. AND VALLEY, G. E. Cathode Ray Tube Displays. 1948.

ENGINEERING.

ALLEN, J. Scale Models in Hydraulic Engineering. 1947.

GEOLOGY.

PEARL, RICHARD M. Popular Gemology. 1948.
SHERLOCK, ROBERT LIONEL. The Permo-Triassic Formations. 1947.
U. S. BUREAU OF MINES. Mineral Resources of the United States. 1948.

HISTORY.

ATKINS, EDWIN FARNSWORTH. Sixty Years in Cuba. 1926.
BURCHARD, JOHN ELY. Q.E.D. M.I.T. in World War II. 1948.

MANUFACTURE.

HAINES, RAY E. The Home Crafts Handbook. 1948.

MATHEMATICS.

ORE, OYSTEIN. Number Theory and its History. 1948.
RIDER, JOHN FRANCIS AND USLAN, SEYMOUR D. Understanding Vector and Phase. 1947.
SCARBOROUGH, JAMES BLAINE. Fundamentals of Statistics. 1948.

METALLURGY.

WILLIAMS, ROBERT S. AND HOMERBERG, VICTOR O. Principles of Metallography. Fifth Edition. 1948.

NATURAL HISTORY.

OSBORN, FAIRFIELD. Our Plundered Planet. 1948.

PHYSICS.

AMERICAN PHYSICAL SOCIETY. DIVISION OF ELECTRON OPTICS. Preparation and Characteristics of Solid Luminescent Materials. 1948.

FAIRES, VIRGIL MORING; BREWER, ALEXANDER V. AND SIMMANG, CLIFFORD M. Problems on Applied Thermodynamics. Revised Edition. 1948.

ROSENFELD, L. Nuclear Forces. 1948.

ROTHERY, WILLIAM HUME. Atomic Theory for Students of Metallurgy. 1948.

PLASTICS.

BROWN, D. WARBURTON. Handbook of Engineering Plastics. 1946.

RADIO.

STRUTT, MAXIMILIAN JULIUS OTTO. Ultra and Extreme Short Wave Reception. 1947.

PUBLICATIONS RECEIVED.

Fundamentals of Physical Science, by Konrad Bates Krauskopf. Second Ed., 676 pages, 15 × 23 cm., tables, drawings and illustrations. New York, McGraw-Hill Book Co., 1948. Price, $4.50.

Vacuum Tube Amplifiers, edited by George E. Valley, Jr. and Henry Wallman. 743 pages, 16 × 23 cm., tables, drawings and illustrations. New York, McGraw-Hill Book Co., 1948. Price, $10.00.

The Specifications and Law on Engineering Works, by Walter C. Sadler. 493 pages, 14 × 22 cm. New York, John Wiley & Sons, Inc.; London, Chapman & Hall, Ltd.; 1948. Price, $5.00.

Simplified Design of Structural Timber, by Harry Parker. 218 pages, 13 × 20 cm., tables and drawings. New York, John Wiley & Sons, Inc.; London, Chapman & Hall, Ltd.; 1948. Price, $3.25.

Physical Geology, by Chester R. Longwell and others. Third Ed., 602 pages, 15 × 24 cm., tables, drawings and illustrations. New York, John Wiley & Sons, Inc.; London, Chapman & Hall, Ltd.; 1948. Price, $5.00.

Nuclear Radiation Physics, by R. E. Lapp and H. L. Andrews. 487 pages, 15 × 22 cm., tables, drawings and illustrations. New York, Prentice-Hall, Inc., 1948. Price, $6.00.

Radio at Ultra-high Frequencies, Volume II. (1940–1947), edited by Alfred N. Goldsmith and others. 485 pages, 15 × 23 cm., tables, drawings and illustrations. RCA Review, Radio Corp. of America, RCA Laboratories Division, Princeton., N. J., 1948. Price, $2.50.

Supersonics—The Science of Inaudible Sounds, by Robert Williams Wood. 162 pages, 13 × 20 cm., drawings and illustrations. Brown University, Providence, R. I., 1939. Price, $2.00.

Conversion of Petroleum, by A. N. Sachanen. Second Ed., 602 pages, 15 × 23 cm., tables and drawings. New York, Reinhold Publishing Corp., 1948. Price, $11.00.

Natural Philosophy Through the Eighteenth Century and Allied Topics (Commemoration Number to mark the 150th Anniversary of the foundation of The Philosophical Magazine), edited by Allan Ferguson. 164 pages, 17 × 25 cm., Port. London, Taylor & Francis, Ltd., 1948. Price, 15s (paper).

The Stuff We're Made of, by W. O. Kermack and P. Eggleton. 356 pages, 13 × 19 cm., tables and illustrations. New York, Longmans Green & Co.; London, Edward Arnold & Co.; 1948. Price, $3.00.

Sources of Engineering Information, by Blanche H. Dalton. 109 pages, 16 × 24 cm. Universtiy of California Press, 1948. Price, $4.00.

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BOOK REVIEWS.

TWO-DIMENSIONAL FIELDS IN ELECTRICAL ENGINEERING, by L. V. Bewley. 204 pages, 16 × 24 cm., drawings and illustrations. New York, The Macmillan Co., 1948. Price, $5.50.

This most worth while book by Professor Bewley fulfills a need for a text which covers some of the introductory problems of field theory in several branches of engineering. It serves admirably in attempting to bridge a gap between various subjects which require field treatment and as a new and perhaps more basic and sound approach to problems in electromagnetic fields and hydrodynamics than has been used previously.

This new book is of unusual interest in that the subject matter presents the mathematical and physical concepts through illustrative problems which are quite practical. The fact that these problems are drawn from several fields emphasizes the power of the field treatment as a working tool, not only for the student but for the practicing engineer. It is seen to be an aid in precise and accurate reasoning, coupled with an easy means of more readily understanding the mathematical results.

The level on which the book is written is that of a senior student in electrical engineering, and it presupposes a knowledge of calculus and differential equations. Through practical illustrations the reader is led through many phases of mathematical physics, including elements of the theory of functions, the Cauchy-Riemann equations, Laplace's equation, sources and sinks, contour integrals, conformal mapping and the important Schwarz-Cristoffel transformation, and the theory of images. These subjects and others are amply illustrated with practical problems such as: eddy current and skin effects, various shaped electromagnetic fields, vortex flow, Bordas mouthpiece, and many others.

From the description listed above, it may rightly be inferred that the bulk of the work consists of solutions of Laplace's equations for particular boundary conditions. Most subsections of the book have collections of problems useful for the classroom and for self study, serving to stimulate thinking along the generalized ideas presented in the various chapters. In addition to the problems listed, it may be good mathematical exercise to re-plot many of the figures in the text starting with the basic equations for the physical concepts.

S. CHARP.

HIGH FREQUENCY MEASURING TECHNIQUES USING TRANSMISSION LINES, by E. N. Phillips, W. G. Sterns, and N. J. Gamara. 58 pages, diagrams, 21 × 28 cm. New York, John F. Rider Publisher, Inc., 1947.

This publication attempts to formalize some of the techniques involved in carrying out high frequency measurements using a slotted concentric transmission line. The procedures outlined have been evolved and are used to answer the needs imposed by measurements in the ultra-high frequency spectrum, where the slotted concentric transmission line is almost the only instrument available to measure physical quantities such as wave length, impedance, velocity of propagation, electrical length, and attenuation in four terminal networks.

The following particular measurement techniques, which can be made with a standardized slotted concentric transmission line, are described: surge impedance and electrical length of the slotted transmission line; measurement of the load impedance attached to the load end of the slotted line, using either a knowledge of all the line constants or by a short circuit method which does not require a knowledge of the series components which connect the load to the line; method of correction for finite attenuation in the measuring section of the line and for attenuation in cable sections; far-end cable load measurements by a method dependent upon short circuit, or a double load, or surge impedance; determination of the electrical characteristics of radio frequency transmission cable section, such as surge impedance and propagation constant; and the determination of the length of ultra-high frequency cable by the procedure commonly utilized in low-frequency communication circuits.

The authors present the techniques in a series of data sheets which list: the order in which a particular measurement is made; the procedure of making the measurement; a sketch showing

the section of the line where the particular measurement is made; and the formula or other pertinent data necessary to make a computation for the physical quantity under investigation from the quantities measured as noted under procedures. These data sheets comprise the major portion of the booklet.

Although there is a wealth of information included, there is much lacking to make this publication of use to the reader on a first reading. Certain terms are introduced in early sections and are either not defined or are defined in later sections. As a result, some sample calculations are made with no statement on the data sheets as to the algebraic form of the equations which are being solved. Many of the diagrams are inadequately labeled or lack identification. Typical of this latter fault is the frequent reference to a Transmission Line Calculator or "Smith Chart," which chart is not shown until some time after its introduction, and then it is illustrated with neither explicit instructions for the use of such diagram, nor even with an explanation as to what the various lines on the chart represent. As a result, the interested reader must study the data sheets in detail and follow through all the numerical examples in order to understand clearly what is being done.

In spite of the shortcomings noted above, it is felt that this booklet may find applications as a reference work in laboratories concerned with ultra-high frequency measurements, and for engineers concerned with such work.

S. CHARP.

TELEVISION—HOW IT WORKS, by John F. Rider. 203 pages, 21 × 28 cm., drawings and illustrations. New York, John F. Rider, 1948. Price, $2.70 (paper).

Typical of many other John F. Rider publications, "Television—How It Works" is written expressly for the radio serviceman. The book gives a thorough, practical, non-mathematical approach to the underlying principles of television with the major emphasis placed, of course, on receiving rather than transmitting equipment.

The flow of text material follows a logical pattern, opening with general background material and then proceeding smoothly from the antenna to the sound and picture reproducers. Throughout the text, frequent reference is made to the circuitry of a number of the receivers on the market today.

Although the book was written by four different authors, the over-all job of editing and coordination has been very well done, so that there is no overlapping nor conflict from chapter to chapter.

There are several statements made in the text which may be misleading to the serious reader. For instance, in Chapter 3 on Television Receiving Antennas, the impression is created that all reflectors have a tendency to raise the input resistance of a dipole, whereas the input resistance can be either raised or lowered by the parasitic reflector depending upon spacing and length. Also, in Chapter 6 on The Video I-F and Detector Section, it is stated that the curves of individual i-f. stages are additive to produce the over-all i-f. curve. Actually, the individual i-f. stage curves multiply together to give the over-all response. The book contains very few references to other sources of material, and it is hoped that this situation will be rectified in any future editions by the inclusion of a bibliography or footnote references for the reader who wishes to broaden his knowledge on the subject of television.

The final chapter on Alignment and Servicing is quite general, but none the less it is as complete as possible, barring the actual inclusion of individual receiver manufacturers' maintenance data.

This book is recommended not only to the serviceman, but to anyone interested in the fundamentals of television systems. It is believed that it can be particularly valuable to the purchasers of "build-your-own" television receiver kits.

ROBERT S. GRUBMEYER.

READINGS IN THE PHYSICAL SCIENCES, edited by Harlow Shapley and others. 501 pages, 16 × 24 cm., drawings. New York, Appleton-Century-Crofts, Inc., 1948. Price, $3.00.

The aim of the editors in preparing this book is to bring to the general student an understanding of the fundamental nature of the physical world and the skills by which this nature is

discerned. The book is a collection of fifty-eight articles abstracted from published papers, books, and lectures in several scientific fields of endeavor, with emphasis on contemporary work. But the writings of early workers have not been neglected, since reference to their labors seems to give perspective to a volume which not only attempts to present some of the principles of the scientific method, but also, through the selections, a brief history of science.

The choice of articles is not at all haphazard. A definite plan was in mind, namely, to approach the problems in science by five paths: history; an examination of the scientific method and its implications; research; tools and apparatus; and bibliographies in the fields considered. Original articles such as those by Galileo, Newton, and Copernicus, to mention a few, attune one more readily to appreciate the problems encountered in the present.

The mental attitude of the scientist, as it develops an eagerness for knowledge through the use of observation and experiment, serves to illustrate the scientific method.

But science is based upon research, and the articles by some of the greatest research men of our times and of the past help to make the stories of some of their work quite vivid. And research without tools is impossible. The need for the latter, and how they help us to learn more and more about the unknown in interrelated fields becomes apparent when it is realized that discoveries and developments of tools in one field are often used in other fields which may not be too closely related.

The plan of approach to the appreciation of the status of scientific achievement today is carried out by a series of specialized articles in each of the following fields: science and scientific method; astronomy; geology; mathematics; physics; and chemistry. Each of these six parts of the book includes a good-sized bibliography for further and more detailed readings in the subject.

While the editors are credited with compiling the works of the various authors, the original works themselves, mostly written in English, have a style and clarity individual to the scientist-writer. As a result, the reader is carried along by the sheer intense interest which the scientist imparts to his story. When Franklin describes his kite experiment, it is done so explicitly that almost anyone could repeat and observe the phenomena. The article by Sir James Jeans on "Exploring the Atom," written in his philosophical style, tells the story of the elementary particles of physics in a factual, yet a most readable manner. As a result, the reader, while not necessarily a scientist nor one in training for a career in science, can gain some insight into the minds of two scientists of widely varying interests.

Nor are modern day problems neglected. The controversial Tennessee Valley Authority is introduced through an article by David E. Lillienthal and the abstract of the now famous Smyth report "Atomic Energy for Military Purposes" brings the reader to face face with aspects of science of interest to our national and international welfare.

While not a text book as we ordinarily consider some books, this volume would serve admirably for a course in the survey of the sciences, or the history of science, or simply one concerned with readings in the physical sciences.

S. CHARP.

ENGINEERING CONTRACTS AND SPECIFICATIONS, by Robert W. Abbett. Second ed., 327 pages, 15 × 24 cm., tables. New York, John Wiley & Sons, Inc.; London, Chapman & Hall, Ltd.; 1948. Price, $3.75.

In this second edition of a book on how to write engineering contracts and specifications from an engineering point of view, the author, a consulting engineer, presents some of the legal and business aspects of the engineering profession in compact form, making this book most suitable as a ready reference as well as a text book. Originally written as a text book for college students, it should be of interest to practicing engineers, architects, contractors, and all persons who are interested in the fundamental legal aspects of this subject.

Basic principles are stressed throughout the volume. The twelve chapters include the following subjects: legal considerations and relationships among engineers, contractors, and

owners; elements of contracts, liens, and labor laws; types of construction contracts; bidding procedures; insurance matters of interest to engineering and construction work; surety bonds and arbitration; engineering services contracts; and specifications determination and writing.

The sections on contracts are clearly written and are quite expository, covering such forms of contracts as competitive bid, lump sum, unit price, and cost plus. The bidding procedures commonly encountered in engineering construction work are outlined and there are reproduced complete samples of Advertisements to Bid forms in current use. Likewise, in the several sections on contracts, examples are given of current "standard" forms. These contracts are of a time-tested form and represent sound current practice in the United States. They are included primarily to illustrate the text and may, at the same time, serve as a guide in the preparation of similar documents for specific projects.

While throughout the book the various specification, bid and contract methods are discussed with emphasis along the lines of private practice, the comparative government procedures for public works projects are examined. This comparison between private and public working arrangements is one of the most important features of this book. This is the reason that it is so different from other volumes treating contracts from the engineer's point of view.

Many engineering schools do not require their students to study the legal aspects of the profession for which they are in training. It would be most advantageous if at some time in his training the student were to read a book of this type, if for no other reason than to make him realize some of the legal responsibilities of a practicing engineer.

S. CHARP.

INTRODUCTION TO APPLIED MATHEMATICS, Francis D. Murnaghan. 389 pages, 16 × 23 cm. New York, John Wiley & Sons, Inc.; London, Chapman & Hall, Ltd.; 1948. Price, $5.00.

Professor Murnaghan's book, based on a one-year graduate course which he gave for two decades at Johns Hopkins University, should prove a welcome addition to the growing list of mathematical works published in recent years for the benefit of scientists and engineers.

Chapter 1 consists of a clear presentation of cartesian vector analysis in two, three, and n dimensions. Chapter 2, entitled "Linear Vector Functions," includes a presentation of the concept of characteristic values and characteristic vectors. Chapter 3 presents a concise discussion of the theory of orthonormal functions. The functions of the orthonormal set are treated as base-vectors, so that this chapter should serve as a simple introduction to the study of function-spaces. Chapter 4 deals with orthogonal curvilinear co-ordinates in two and three dimensions, and includes a discussion of vector analysis in such systems. Chapter 5 presents a discussion of the most common methods of solving Laplace's equation in two and three dimensions, with physical interpretations in terms of electrostatics. Chapter 6 gives a straightforward presentation of the theory of spherical harmonics and Bessel functions, and in Chapter 7 there is given a very simple and lucid presentation of the one-dimensional boundary value problem. The excellent discussion of the Green's function deserves particular note. Chapter 8 gives a very clear discussion of the Fredholm and Hilbert-Schmidt theories of linear integral equations. Chapter 9 is devoted to the calculus of variations, with emphasis on applications to analytical mechanics. The concluding chapter deals with operational methods for the solution of initial-value problems of ordinary linear differential equations.

In a book of moderate length it is quite impossible to treat adequately all the most common methods of applied mathematics. In particular, the reviewer regrets that it was necessary to confine the discussion of complex-variable methods to brief sections in Chapters 4 and 5, and that the opening chapters do not contain an introduction to the theory of tensors. Numerous other extensions of the contents could also be recommended. Nevertheless, Professor Murnaghan deserves great credit for his clearly written presentation of some of the most important mathematical methods now employed in scientific research. Finally, it may be remarked that the author has wisely chosen the level of rigor, avoiding extreme pedantry on the one hand and looseness on the other.

BERNARD EPSTEIN.

INDUSTRIAL ELECTRONICS REFERENCE BOOK, by Electronics Engineers of the Westinghouse Electric Corp. 680 pages, 23 × 30 cm., tables, drawings and illustrations. New York, John Wiley & Sons, Inc.; London, Chapman & Hall, Ltd.; 1948. Price, $7.50.

Most electrical engineers concerned with the production and distribution of electric power at commercial frequencies are familiar with the book entitled "Electric Transmission and Distribution Reference Book" written by the electrical engineers of the Westinghouse Electric Corp. Now out of this same large organization, authored by thirty-seven expert physicists and electronics engineers, comes a reference work with the most modern information available today on the industrial applications of electronics. From the first page to the last the reader is made well aware that the correct facts are presented about the various subjects considered. In the opinion of this reviewer, this reference work has no equal in regard to scope and clarity of presentation.

The Industrial Electronics Reference Book was written by a group of practicing engineers and it is meant to be read primarily by other practicing engineers who may be concerned with the application and utilization of electronic apparatus as tools in industry. In addition, research workers and designers engaged in the development of new industrial devices may gain a more far-reaching understanding of the possibilities and limitations of industrial equipment as used today. Students may find this book of material aid, and it may have application for use in courses in industrial electronics on either the undergraduate or graduate level. The more than one thousand references, contained in bibliographies to be found at the end of most of the chapters, cover specific problems mentioned in the book.

The work first introduces the fundamental and theoretical concepts of electron production and control, with some consideration of the theories of emission and forces on electrons in the presence of electric and or magnetic fields. Design, construction, and operation of the various types of electronic and gaseous tubes are then considered. The field is rather completely covered, as witness sections devoted to: electrical conduction in gases; vacuum tubes, klystrons, and magnetrons; hot and cold cathode gas tubes and their static and dynamic characteristics; photoelectric devices; X-ray tubes; cathode-ray tubes; and ultraviolet radiators.

A theoretical and practical treatment is accorded electronic components and circuits, emphasizing the use of electronic devices as rectifiers, amplifiers, oscillators, and controllers. A good basic theory of antennas and transmission lines is presented, with discussions of some experimental measuring techniques, the use of a transmission line chart of the type used by communications engineers, and certain design curves for antennas.

The basic design features of many pieces of industrial equipment are reviewed in the remainder of the book, in many instances setting forth their limitations. Typical of the subject matter covered in these sections are: power rectifiers and inverters; radio frequency heating; power line carrier systems; electronic instrumentation; and electronic controllers. Because of the rapidly changing aspects of electronic applications, the sections devoted to specific pieces of equipment are written somewhat thinly so that many basically different pieces of apparatus can be included in such a survey. That material which is presented is done so authoritatively and represents the most up-to-date information available.

While the book is primarily a reference work, it can be safely said that if any engineer were to read and digest the subject matter to be found in this work, he would have quite a liberal education in the subject of industrial electronics as the status of the art is today.

S. CHARP.

SCIENCE, SERVANT OF MAN, A LAYMAN'S PRIMER FOR THE AGE OF SCIENCE, by I. Bernard Cohen. 362 pages, illustrations, 14 × 20 cm. Boston, Little, Brown and Co., 1948. Price, $4.00.

With the increasing emphasis on scientific research by government agencies, the layman who foots the bill should be interested in knowing why he should be expected to do so, and what direction such scientific activities should take. Dr. Cohen has presented an instructive and interesting account of the potentialities of pure scientific research as a source of practical benefits.

Prompted by the National Science Fund (National Academy of Sciences), Dr. Cohen has had the benefit of assistance from many specialists, including several whose work he describes. The author, who is an instructor in the History of Science at Harvard University, has written other books on the history of science and is well qualified for the task he has undertaken.

Moreover, this is no bare recital of facts and dates about important inventions and discoveries. To clarify the importance of pure scientific research for the layman, the book presents the practical consequences of such research by means of selected case histories. In these, emphasis has been placed on the experience of the scientist himself, tracing the history of ideas, how they were discovered, the effect they had on the state of science and how they were put to use in the service of mankind.

The introductory chapters review the conditions necessary for scientific discovery and the point is made that discoveries are often dependent upon the existence of a proper scientific atmosphere. This explains in part the occurrence of simultaneous discovery as well as the rediscovery of older facts, known but not exploited. In this latter case a discovery may be made at a time when the scientific atmosphere is not propitious and it consequently lies dormant until such time as conditions are more favorable for futher investigation.

The case histories on the application of science are presented in three categories. First is that in which the practical applications of fundamental research are merely the "by products of the research for truth in the scientific laboratory." Examples are to be found in some of the new weed-killers which derived from investigating the question "Why do plants bend toward the light?", and in nylon, which was the outgrowth of research into high polymers.

The second type involves the situation in which a practical application seems likely and the research is directed towards that end. Instances of this type are the work done on blood groups and blood transfusions, and the development of a satisfactory hybrid corn. Generally such research is distinguished by being aimed at supplying a definitely felt need.

The third group of case histories is more unusual. In these the scientific facts had been known and studied for a long time before a use could be found for the knowledge. A striking example is the use made of "foraminifera" which has been studied by paleontologists in the various fossil formations and which, in the last few years when oil was vital, formed the basis of new techniques in petroleum prospecting. The author emphasizes that if this basic knowledge of these fossils had not been available, it would not have been possible to make this practical application in an entirely different field. He also points out the improbability of any group of scientists having devised a particular application until the scientific background had been set. For example, the visualization of any such technique as the use of X-rays in medicine would have been undoubtedly out of the question until the discovery of X-rays.

In two concluding chapters Dr. Cohen discusses science as the servant of man and how we can get the most out of science. He points out that society as a whole is responsible for what is done with the results of scientific research, and that the scientists should not be blamed if some development such as atomic energy is used for bombs instead of peaceful purposes.

Dr. Cohen has produced a stimulating and thought-provoking book. It not only entertains and instructs, but it conveys a message as to the importance of a free and untrammeled science, which should be liberally supported in the knowledge that practical applications generally result, even if they are unseen at the time. For those desiring to read further, a helpful bibliography is included with indication by use of a symbol of those titles which may prove most interesting to the layman.

G. E. PETTENGILL.

COMPUTING MECHANISMS AND LINKAGES, by Antonin Svoboda, edited by Hubert M. James. 359 pages, 16 × 23 cm., tables, drawings, and plate. New York, McGraw-Hill Book Co., 1948. Price, $4.50.

This volume of the Radiation Laboratory Series was written by one of the best designers of linkage computers, one who had studied and designed these particular computing elements for many years prior to the past war and his association with the Radiation Laboratory. As

a result the work is one which is authoritative, representing some of the ideas and methods developed by the author and his close foreign collaborators.

The subject matter of the book is concentrated wholly in the field of the design of continuously acting computing mechanisms. In particular, it deals principally with the mathematical design of elements for bar-linkage computers. Such computers have a wide field of application, especially where the computer must be small and light-weight, as when it is to be carried in an aeroplane or guided missile. While in this volume there will be found some comment on the mechanical features of bar linkages, the mechanical design of these components is not discussed in detail, just sufficiently to give the analyst or analytical designer a basis for reasoning in the development of the "cells" for a complete computer.

The author considers a complex mechanical computer to be composed of a number of elementary computers which are essentially basic bar linkages and mechanisms which perform the elementary arithmetic functions. These latter mechanisms are described and analyzed in detail with the aid of clear sketches. Among the elements so presented are: eight varieties of adders or differentials; slide and nomographic multipliers; mechanical resolvers and component solvers; six varieties of cams; and friction wheel and ball integrators.

It is shown that simple bar linkages can be designed to perform all the elementary functions noted above except to establish relations between differentials, that is, they cannot perform the functions of integrators. It is pointed out, however, that these linkages serve quite well as function generators, although in many cases the design is not unique.

Problems of bar-linkage computer design are considered with emphasis on those mechanisms having one and two degrees of freedom. Examples of design procedures and the theory of design and operation are amply illustrated for the cases of: harmonic transformers, singly and in series; the three-bar linkage; and linkage combinations with one degree of freedom. In each of these categories an analysis is made of the errors involved due to structural defects as well as those due to non-ideal fitting of functions. Nomographic and geometric methods of analysis are presented. Two degree-of-freedom linkages and function generators are considered, as well as an analysis of the adjustment of linkage constants.

Throughout most of the book the reader is shown, by worked-out examples, how to apply the design theory of these mechanisms.

This book does not seem to be written for a general type of reader, but rather for one definitely interested in linkage desgin. It should, therefore, appeal to mechanical engineers and instrument designers, especially those designers who continually have to meet specifications for small size and light weight devices.

S. CHARP.

ELECTRONS IN GASES, by Sir John Townsend. 166 pages, 15 × 24 cm., tables and drawings. London, Hutchinson & Co., Ltd., 1947. Price, 25s.

This monograph on the actions of electrons and ions in gases was written by a master of both experimental technique and theoretical concepts, and should be of interest to every serious advanced student or worker in the field of experimental electronic physics and engineering. Patterned somewhat after the author's earlier work "Electricity in Gases" (1915) the book contains an account of some complete investigations of the motions of electrons in gases. The point of view is not that of a description of electronic motion as is understood in applications to electron lenses, but rather a consideration of electron motion as it affects our knowledge of atomic physics.

The book deals primarily with the experimental side of this subject, starting out with an explanation of how the effects of the collisions of electrons with molecules are deduced from experiments with small currents, in uniform fields of force, and in gases at various pressures.

From a knowledge of the distribution of the velocities of agitation and the mean free paths, the author derives expressions for the coefficient of diffusion of these electrons as they move in a stream, showing that this coefficient is equal to $l\bar{U}/3$, where l = mean free path and $\bar{U}$ = mean velocity of agitation. Electronic motion in electric and magnetic fields is con-

sidered in the presence of diffusion and expressions are derived in forms which allow their comparison with the results of experiment.

While the author presents much material which is in the nature of original contribution to this restricted field, he deals comprehensively with the work of other physicists. Experiments measuring the diffusion of streams of electrons and ions are described, indicating the effects due to the presence of small amounts of water vapor. The mobilities and energies of electrons during motion and as a result of collisions are considered in gases such as: hydrogen, argon, neon, and helium. Numerous graphs and tables are presented showing the relationships between gas pressure, electric field, mean velocity and diffusion ratio.

The author's theories on ionization by collision are deduced from the early experiments which he conducted as far back as 1900. The many objections which certain leading scientists made to his theories are discussed, and it is shown that on the basis of further experiments by the author and others that ionization is definitely caused by collisions of electrons. Again with regard to the determination of ionization potentials in several gases, experiments as carried out by many physicists are described and their results tabulated. It is shown that the energy losses as a result of collisions vary for different gases and for different electron energies. A theory of the action of positive ions is presented and it is shown to be in accordance with the experiments of the discharges in uniform fields and of discharges between coaxial cylindrical electrodes.

The one fault which this reviewer finds with the book is the lack of reference to any experimental work after the year 1938, the greatest number of references being dated in the first two decades of this century. While it may be true that most of the basic experimental work was done many years ago, still it would seem that our scientific journals must surely contain worth while material on the subject of electrons in gases from the point of view considered in this monograph. Their absence seems to make the book somewhat incomplete.

S. CHARP.

BOOK NOTES.

TABLES OF BESSEL FUNCTIONS OF FRACTIONAL ORDER, prepared by the Computation Laboratory of the National Applied Mathematics Laboratories, National Bureau of Standards. Volume I, 413 pages, tables, 20 × 27 cm. New York, Columbia University Press, 1948. Price, $7.50.

The Computation Laboratory of the National Applied Mathematics Laboratories, formerly known as the Mathematical Tables Project, has been preparing useful tables for ten years. This latest volume comprises tables for Bessel functions of fractional order $J_\nu(x)$ for $\nu = \pm\frac{1}{4}, \pm\frac{1}{3}, \pm\frac{1}{2}, \pm\frac{2}{3}$. These functions are important in their own right and also can be used as approximations to solutions of more complicated differential equations encountered in wave theory. Practical applications of the functions may be found in the fields of elasticity, heat conduction and hydrodynamics. The bibliography supplies a guide to some of these applications while the introduction gives helpful hints on the use of the tables.

G. E. P.

THEORY OF PROPELLERS, by Theodore Theodorsen. 164 pages, illustrations, charts, 16 × 23 cm. New York, McGraw-Hill Book Co., Inc., 1948. Price, $6.00.

This work is based on a series of reports by the National Advisory Committee for Aeronautics, and incorporates the developments which resulted from the research program on propellers conducted by the N.A.C.A. during the war. The material is presented in nine chapters with several appendices and an index. Several illustrations are shown on model wake spirals and the book also contains many diagrams and charts. The volume is published as one of the McGraw-Hill Publications in Aeronautical Science.

W. P.

ENGINEERING APPLICATIONS OF FLUID MECHANICS, by J. C. Hunsaker and B. G. Rightmire. 494 pages, illustrations, 15 × 23 cm. New York, McGraw-Hill Book Co., Inc., 1947. Price, $5.00.

Two members of the faculty of the Massachusetts Institute of Technology have written this introductory textbook on fluid mechanics, based on some twelve years of experience in teaching an undergraduate course in the subject. Emphasis has been placed on an adequate understanding of flow phenomena rather than familiarity with many practical devices.

The first part of the volume considers the more general principles of fluid mechanics, while the second part treats of the theory in particular applications. Among the topics discussed in this latter section are wing theory, lubrication, both hydrodynamic and boundary hydraulic turbines, pumps, propellers, fluid coupling and torque converters. Because of the importance of models in cases of confused type of flow, the authors have treated the theory of dimensions and physical similitude at some length. A selected bibliography is appended to most chapters and the problems have been gathered together in one section at the end of the volume.

G. E. P.

STRENGTH OF MATERIALS, by Joseph Marin. 464 pages, illustrations, 16 × 24 cm. New York, Macmillan Co., 1948. Price, $4.75.

The material in this book has been selected for use as a text in a first course in strength of materials. The subject of the book is divided in four parts—simple stresses, combined stresses, statically indeterminate stresses, and special topics compiled into twelve chapters and two appendices. Part 1 covers simple tension and compression, torsion, bending and axial loads; part 2, combined stresses; part 3, statically indeterminate stresses; and part 4, riveted and welded joints. At the end of each chapter there is a collection of problems. The book is well illustrated and complete with well arranged contents and index.

W. P.

FUNDAMENTALS OF STATISTICS, by J. B. Scarborough and R. W. Wagner. 144 pages, tables, 16 × 23 cm. Boston, Ginn and Company, 1948. Price, $2.40.

A textbook presenting in rather concentrated form the fundamental principles and techniques of statistical analysis. Mathematics through elementary calculus is a prerequisite, as quite detailed proofs are offered of some of the theorems. Problems and answers are included.

G. E. P.

PROBLEMS ON APPLIED THERMODYNAMICS, by V. M. Faires, A. V. Brewer and C. M. Simmang. Revised edition, 151 pages, tables and diagrams, 15 × 23 cm. New York, Macmillan Company, 1948. Price, $1.70 (paper).

Some eleven hundred problems are presented in this paper-bound volume. Designed primarily for use with Faires' *Applied Thermodynamics*, they are adaptable to any text emphasizing the general energy equation and which uses terminology in accordance with the more recent codes and standards. Since some instructors may prefer not to have answers given, they have been omitted for some problems. Steam tables and charts are given in an appendix.

G. E. P.

THE THEORY OF MATHEMATICAL MACHINES, by Francis J. Murray. Revised edition, 139 pages, diagrams, 21 × 28 cm. New York, King's Crown Press, 1948. Price, $3.00.

This interesting presentation on various mathematical machines now appears in a revised edition. Opportunity has been taken to correct such errors as had been noted and to make some additions. These latter are principally in Part III dealing with the solution of problems and include two new chapters on "Electronic Digital Computers" and "Accuracy, Noise and Stability." The addition of an index will also make the material more useful.

G. E. P.

NOTES FROM THE BIOCHEMICAL RESEARCH FOUNDATION.

Abstract of **The Activation Mechanism and Physico-Chemical Properties of *Clostridium histolyticum* Proteinase.**—WALTER KOCHOLATY AND LAURA E. KREJCI (*Archives of Biochemistry*, **18**:1, 1948). *Cl. histolyticum* proteinase has been obtained as an apparently homogeneous protein by a combination of precipitation procedures and electrophoresis. It gives no positive reaction for sulfhydryl or disulfide groups, and contains very little tyrosine or tryptophane. Like pepsin, it exhibits increased electrophoretic mobility in solutions of increased ionic strength.

The enzyme shows increased activity in the presence of ferrous ions and cysteine. The extent of hydrolysis when enzyme and activator are added simultaneously to the subtrate was found to be the same as when addition of the activator is deferred until digestion by the unactivated enzyme is complete. These results were interpreted to indicate that the greater activity in the presence of the activator is the result of a change in, or extension of, the specificity of the enzyme.

CURRENT TOPICS.

A Simple, Accurate Microhardness Testing Device (*Metal Progress*, Vol. 54, No. 2).—This apparatus, a wartime development in Europe, uses an inverted metallographic microscope, whereby the exact location of the spot to be tested can be fixed. The objective is then replaced by another holder in which a pyramidal diamond is accurately centered, and specimen is lowered onto the diamond's point. A counterbalanced lever system regulates the pressure between diamond and specimen (the indenting load) between limits of 0.5 and 500 g., and the resulting impression is measured by micrometer eyepiece in the usual manner. The tester differs from other microhardness testers principally because of the facts that the necessary load is applied direct to the specimen (thus simplifying the construction) and that the specimen instead of the indenter is movable. The wide range of utility for microhardness testing can be illustrated by the following examples, which have been chosen primarily as applications to purely practical questions: testing of a wire 0.004 in. in diameter; determination of hardness of the working surface of small dental drills, thin twist drills, metal fragments and file teeth; testing of metal foils for hardness; and the determination of the hardness of thin surfaces, such as electrodeposited layers. Also, good results can be obtained by using a section of metal cut at an acute angle to the surface. The apparatus is also well adapted to measuring the hardness of brittle materials, by using a sufficiently small indentation load. This simple device can be used by any first class laboratory technician, once he has been trained in the routine.

Pioneer Aluminum Crane of Canadian Design (*Canadian Machinery and Manufacturing News*, Vol. 59. No. 9).—The latest, and perhaps most interesting adaptation of aluminum is its use for the structural members of a crane about to be installed at Arvida. It was built for the rod mill of the Aluminum Co. of Canada. Designed and fabricated by Dominion Bridge Co., the new crane is of the lattice girder type and has a lifting capacity of 15 tons. The 97-ft. girders are fabricated entirely of high strength aluminum alloys, extruded in the shapes of channels and angles and rolled into plates. The rivets and bolts used in fabrication are also of special alloyed aluminum.

The strength of the aluminum alloys used is approximately the same as that of structural steel, but in order to prevent excessive deflection it was necessary to increase the depth of the girders. To conserve headroom the trolley rails were attached to the inside faces of the girders so that the trolley would not extend above their top surfaces.

The weight of a standard crane fabricated in steel would have been 94,000 lb.; the actual weight of the aluminum crane (complete) is 51,735 lb. As a result of this considerable saving in weight, it was found possible to install a motor of 30 per cent less horsepower than that required for a standard crane. Maintenance will be simpler and less expensive as the crane bridge will never require painting. A reduction in weight of supporting steelwork was also found possible.

Automatic Projector.—LaBelle Industries, Inc., Oconomowoc, Wis., has acquired all sales rights to the PRC automatic slide projector, formerly distributed by the Picture Recording Company, Chicago.

This unit, which has been known to the trade as Model 300 PRC, is now identified as LaBelle Model 301 Automatic Magazine Loading Slide Projector.

In operation, the new LaBelle is different from any other projector in existence. It does all feeding, changing and restacking of slides automatically, efficiently and in perfect order. A pushbutton switch on a remote control cord gives real advantages to the operator, who can stand in front of his audience if giving a lecture, or relax comfortably in an easy chair, away from the projector.

A metal magazine, loaded with either 75 two-by-two ready mounts or 35 glass slides, is inserted into the top of the LaBelle projector. Pressing the control switch releases the slides, one at a time, into a special chamber where they are prewarmed and conditioned for the heat in the projection aperture. The pre-warming operation prevents warping or buckling and insures correctly focused projections.

Each slide moves automatically into the right position in the projection aperture. A superior optical system increases light intensity and projects the image through coated lenses that reduce reflections. The image appears on the screen in sharp detail, always in perfect focus, and remains there until the pushbutton is operated again.

A double-action shutter completely blocks out the picture on the screen when slides are changed. A new view appears instantly, without flickering or the usual slide "wipe."

After leaving the projecting aperture, all slides, kept in correct sequence and proper position, are automatically restacked in an interchangeable metal container at the bottom of the machine. This container, when removed from the projector after an exhibition, can either be inserted into the top for another showing or filed for future use.

The LaBelle Projector makes it unnecessary to handle slides or ready mounts after they are once arranged, and they remain free of fingerprints or scratches. The objective lens is controlled by a "micro-focusing" adjustment. The "micro-tilt" quickly adjusts the alignment of the projected image on the screen.

The LaBelle retails at $125.00, a price that includes a handsomely styled carrying case with a screen in its detachable, standup cover. This new projector appeals to sportsmen, color-photo enthusiasts, school executives, sales managers, advertising men, sales training supervisors, traveling salesmen and lecturers.

Nuclear Charts Prepared by Westinghouse School Service.—Six lithographed wall charts in two colors illustrating the important areas of nuclear physics have been prepared by the Westinghouse Electric Corporation's School Service for use in classes in schools and colleges.

Measuring 25 by 36 in. and made of heavy stock, the charts are accompanied by a 32-page book of valuable supplementary information. The price for the complete set is $1.00.

The first chart portrays ten basic particles important in nuclear physics,

illustrating and describing the proton, neutron, alpha particle, beta particle, gamma ray, deuteron, positron, mesons, and the neutrinos. The second chart explains how nuclei are put together, depicting some 635 isotopes and 75 isomers. It also illustrates and explains mass defect, binding energy, and Einstein's mass-energy formula.

Natural and man-made nuclear reactions are depicted in the third chart which includes solar reactions, natural radioactivity, nuclear fission, as well as typical reactions induced by various kinds of atomic bullets. Chart No. 4 portrays eleven types of apparatus for detecting and inducing nuclear reactions including the ionization chamber, Geiger counter, Wilson cloud chamber, and modern atom smashers.

The fifth chart shows five areas for the useful application of atomic energy. The construction and operation of the atomic pile are described. Illustrations of tracers, research, medical therapy, and the atomic bomb are included.

The last chart covers the major theoretical, experimental, and engineering achievements in nuclear physics, pointing out 38 contributions, from the discovery of natural radioactivity and X-rays to the current developments.

Camera for Diagnosis of Heart Ailments.—The Fairchild Camera & Instrument Corp. has announced that its fully-automatic 70-mm. Fluoro-Record Camera, which has been proven to be ideal for routine and mass radiography, is now available with a film speed-up modification that permits its use in the angiographic study of heart conditions.

A modified version of the original F-212 Fluoro-Record Camera, this new instrument gives increased film transport speed permitting exposures at the rate of approximately 17 every 24 seconds, to provide an adequate record for accurate diagnosis. Each 100-ft. roll of 70-mm. film supplies 375 negatives, 2½ by 3 in., permitting easy reading without high magnification.

Radiologists are now offered added economy and versatility with Fairchild's new gear shift speed changing mechanism which makes the Fluoro-Record Camera available for either angiocardiography or regular chest X-ray purposes.

No-Dip Paint Brush (*Science Illustrated*, Vol. 3, No. 11).—A continuous-flow paint brush, which eliminates the tiresome dipping of the brush in the paint, has been invented by Russell C. Engren, who employed the principle of gravity feed to solve the problem. Engren inserts valve outlets at the bottom of paint buckets and connects them with light, flexible hose to brushes with hollow heels. Paint flows continuously into the brush bristles, subject to control by the bicket valve and a simple clip. Housewives as well as painters tested the Air Flow Brush, found it saved an average of 38 per cent in time and paint. Contractors reported as much as 50 per cent higher painting production per man hour. Saving in brushes is also substantial, since cleaning bristles from heel to tip keeps them useable until they are completely worn out.

Du Pont Makes Titanium (*Nucleonics*, Vol. 3, No. 4).—The Du Pont Company has announced that it has begun the small scale manufacture of titanium metal, a new basic raw material for industrial development. A pilot plant of 100-lb. daily capacity has been successfully placed in operation at the

Newport, Delaware, plant of the Pigments Department. This, so far as the company knows, is the first time ductile titanium metal has been produced for commercial exploration. The U. S. Bureau of Mines has been producing the metal for research purposes.

Reports of the Bureau of Mines and other organizations indicate that the properties of titanium are such that it may be used for reciprocating mechanical parts and in jet engines where heat and pressure are great.

Most titanium metal which has been available heretofore has been in powder form. Du Pont is producing it now in sponge form and will shortly be producing ingots weighing up to 100 lb. Running 99.5 per cent plus of purity, the metal is ductile and can be rolled and drawn readily. It has high resistance to breaking or pulling and has high strength against distortion. The company will supply small samples without charge to industrial and university laboratories for testing.

Stronger than Steel (*Plastics*, Vol. 8, No. 10).—The American Chemical Society reported the development of a new plastic-cloth material which is stronger than steel and withstands shell fragments as successfully as armor plate. Easy to make from common textiles and the polyester type of plastic, the material can be molded into automobile bodies, water pipes, boat hulls and many other useful products. The textiles contributing the greatest strength are woven glass fiber, a synthetic cellulose fiber called Fortisan, tide-cord rayon, nylon, and Steralon, a non-woven cotton cloth originally designed for babies disposable diapers. The report stated that, pound for pound, a multi-layered sandwich of Fortisan and plastic is twice as strong as structural steel.

Plating Tungsten Alloys.—The metal tungsten may have new industrial uses as a result of research at the University of Wisconsin.

A rare, though not precious metal, tungsten's unusual properties have long been known to scientists. They include extreme hardness and the highest melting point of any known metal.

In combination with other metals, tungsten has been used for electrical contact points, light bulb filaments, high speed machine tools, and other electrical equipment.

A method for plating tungsten alloys now has been developed by M. L. Holt, University of Wisconsin professor of chemistry, and his graduate assistants. He recently reported on his work to the Electrochemical Society at its annual meeting in New York.

Professor Holt, assisted by Luther E. Vaaler, plated tungsten alloys on such metals as iron, copper, and brass, giving these metals an extremely hard, heat-resistant outer surface, useful where much friction and wear are encountered.

The alloys which Professor Holt plated were composed of from 5 to 55 per cent of tungsten with nickel, cobalt, or iron.

"The plated tungsten when properly heat-treated is quite hard for an alloy deposit," Professor Holt said, "and resistant to wear and corrosion. Our approach now, of course, is to find ways to plate pure tungsten."

Refining tungsten ore, much of which is mined in Southern China, presents great problems to industry. There is literally nothing in which it can be

melted—the 6000°F. required to melt tungsten is higher than any substance which might be used for a container.

By chemical means the oxide of tungsten is recovered from the ore and heated in an electrical furnace with hydrogen gas. The hydrogen and oxygen combine, leaving tungsten powder which is pressed into bars. The bars are subjected to a heavy electrical current, raising the temperature of the tungsten to a point where it fuses into a rod.

Radiant Heating by Electricity (*Engineers' Digest*, Vol. 5, No. 7).—For many years electrical energy has been employed for room heating and in Great Britain the most popular method is by the use of portable electric fires. In European countries and the U. S. A. a convector type of electric heater is commonly employed, and this is becoming popular in Great Britain for although it is less efficient than the exposed element heater, its fire risk is also less.

Intermittent heating by either of these types of electric heaters is not only uneconomical, but introduces a bad load factor as the use of these units for house heating only partially coincides with the off peak load. These operating inefficiencies can be eliminated and a more convenient and healthy application of electrical energy to space heating secured by the application of low temperature radiant heat by the "Dulrae" system of electric panel warming.

"Dulrae" is a thin fabric, about 1 mm. thick, in which resistance wires are woven, and manufactured in 100-ft. long rolls, 48 in. or 24 in. wide, with multi-wired conductors in the outer edges. The resistances are arranged in such a manner that at multiples of the length, the material may be cut across without injuring the element. The best operating results are obtained by fixing "Dulrae" material to ceilings, and for this purpose the elements are loaded at about 16 watts per square foot, which in normal temperatures will warm the surface of the ceiling to about 90 F. A thermostat, with a differential of plus or minus 1 F., is provided in each individual room for temperature regulation, which, unless intentionally changed, is maintained steadily without requiring manual operation of any kind. To reduce heat losses, the ceiling above the "Dulrae" material is insulated over the whole area.

Where land is of great value and rents are exceptionally high, the installation of a "Dulrae" system is a very economical proposition, for, although electricity for heating costs about four times as much as oil fuel, the saving of labor, and the extra rents receivable for the increased area of floor space (rendered available by the abolition of the boiler-room, fuel chamber, chimney, ventilating shaft, and the stoker's dressing room) show a balance in favor of the electric system.

Blade Milling Machine (*Engineers' Digest*, Vol. 5, No. 7).—A new type of blade milling machine developed by Sulzer Brothers, Winterthur, Switzerland, is a vertical copy milling machine with hydraulic control, rigid spindle and moving table. It is equipped with a normal cylindrical milling cutter which machines the whole length of the blades at one pass in a longitudinal direction. The feed motion of the work table is a combined movement consisting of rotation at a freely adjustable speed and a longitudinal motion controlled by a cam. This cam, which determines the profile to be milled, is mounted on a

second revolving table whose rotary and longitudinal movements correspond exactly with those of the work table. On the cam runs a roller which controls the longitudinal displacement of the two tables by way of a pilot valve and a servomotor in such a way that the roller remains exactly in its central position at all times. If the diameter of the roller is equal to that of the milling cutter, the profile milled is thus an exact reproduction of the cam form. In general two profile cams are used per blade, one being for the front of the blade and one for the back. Blades up to approximately 200 mm. in length can be manufactured on these machines.

Chemical Mist Can Kill Fungi Too.—Blowing a mist of concentrated spray material over trees and fields has proved a notably effective new method of dealing with a good many insect pests. Noting the new equipment developed for this work, farmers and orchardists have been asking the U. S. Department of Agriculture whether it is not practical to use the same type of machinery for fighting plant diseases that are caused by spores of fungus.

At first thought the prospect did not seem encouraging. Nearly all insects move about on the plant they are attacking, and one of the great merits of DDT and other new poisons is that they remain deadly for some time, so that if insects of certain types merely come in contact with a tiny particle of the insecticide remaining on a leaf it causes "jitters" and kills the insect.

Many plant diseases are caused by the germination of spores of a fungus. Millions of these spores move in the air and shower plants constantly. The great majority of the spores die without causing any ill effect. Most drop to the ground. Others land on dry foliage and drop off or dry out. Still others ride on insects which may never drop a spore at a favorable place. But with millions of spores to waste, some land on moist spots on leaves, perhaps in dew drops. These germinate, spread, and multiply. With this situation the prospect did not seem promising for mist application of fungicides. It did not seem probable that the mist particles would cover the leaves well enough to prevent spore germination and the build-up of infection that follows.

With equipment available, however, S. F. Potts of the Bureau of Entomology and Plant Quarantine and A. E. Dimond of the Connecticut Agricultural Experiment Station, have tested the mist blower method of applying a fungicide for control of the anthracnose that attacks sycamores and London planes. They report a fair degree of control—much better than they anticipated.

It will be necessary, the scientists say, to make tests with other concentrated fungicidal sprays, and to observe results with other diseases of plants. But the results open a promising field for further experiment and investigation. The workers do not regard the method as promising for of the fungus causing Dutch elm disease which is carried by an insect with spores deposited in feeding injuries or under the bark where mist blown fungicides do not penetrate.

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